Evaluation of Weather Forecasting Services for the Iowa Department of Transportation

CTRE Project 02-126

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IOWA STATE UNIVERSITY

Final Report • November 2003

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16. Abstract

The objective of the evaluation of the weather forecasting services used by the Iowa Department of Transportation is to ascertain the accuracy of the forecasts given to maintenance personnel and to determine whether the forecasts are useful in the decision-making process and whether the forecasts have potential for improving the level of service. The Iowa Department of Transportation has estimated that the average cost of fighting a winter storm to be about $60,000 to $70,000 per hour.

This final report is to provide an evaluation report describing the collection of weather data and information associated with the weather forecasting services provided to the Iowa Department of Transportation and its maintenance activities and to determine their impact in winter maintenance decision-making.

EVALUATION OF WEATHER FORECASTING SERVICES FOR THE IOWA DEPARTMENT OF TRANSPORTATION

CTRE Project 02-126

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EXECUTIVE SUMMARY

The objective of the evaluation of the weather forecasting services used by the Iowa Department of Transportation (Iowa DOT) is to ascertain the accuracy of the forecasts given to maintenance personnel and determine if the forecasts are useful in the decision-making process and whether the forecasts have potential for improving the level of service. Iowa DOT has estimated that the average cost of fighting a winter storm to be about $60,000 to $70,000 per hour.

This report is to provide an evaluation report describing the collection of weather data and information associated with the weather forecasting services provided to Iowa DOT and its maintenance activities and determine their impact in winter maintenance decision-making.

1. INTRODUCTION AND PROJECT PLAN

This final report is to provide findings to the Iowa DOT of the evaluation that has been made in the Weather Forecasting Services Project Evaluation. This report provides the strategy and methodology to be observed as the technical evaluation is performed for this project. The report also provides a synopsis of the purpose, partnership, organization, test goals, objectives, and a system description. It should be noted that revisions to this plan were developed as work continued with the evaluation of weather services.

Purpose of the Project

Project evaluations such as this are designed to bridge the gap between research and development activities and full-scale deployment of proven technologies. An advantage of an evaluation such as Weather Forecasting Services Evaluation Project is that the tests are conducted under real world conditions in the transportation domain. The purpose of this project is to

- Evaluate the accuracy of FORETELL weather and pavement condition forecasts as compared to forecasts provided by Iowa DOT's contracted weather service (Meridian Environmental Technology) and actual measurements collected from RWIS/AWOS/ASOS weather station sites, improve the safety and efficiency of winter maintenance operations,
- Increase the performance of the highway system, and
- Protect the public investment in our infrastructure.

This is accomplished by using mainline road weather information systems (RWIS), installed at specific sites throughout Iowa. The resulting network of RWIS sites and other data collection apparatus will serve as a baseline for weather forecast and road condition information. In addition, the forecast information is compared to actual weather condition information archived at the Iowa State University's Department of Agronomy in the Climatology and Meteorology laboratory.

Project Partnership

One of the most critical elements for a successful evaluation is the definition of the roles of all partners and the organization. Table 1.1 illustrates respective areas of involvement on which the partners have agreed.

Project Organization

The weather forecasting service evaluation project is comprised of a combination of the state of Iowa DOT, Iowa State University staff and faculty, CTRE staff, consultants, and industry representatives. Figure 1.1 shows the general structure.

Table 1.1. Team partners and roles

Partner	Role
Iowa DOT	Oversight and Advisory
Castle Rock Consultants	System Design and Development
Meridian Environmental Technology	System Design and Development
Center for Transportation Research and Education (CTRE)/ Iowa State University	Coordinate Development and Execution of the Evaluation Plan and Individual Test Plans.

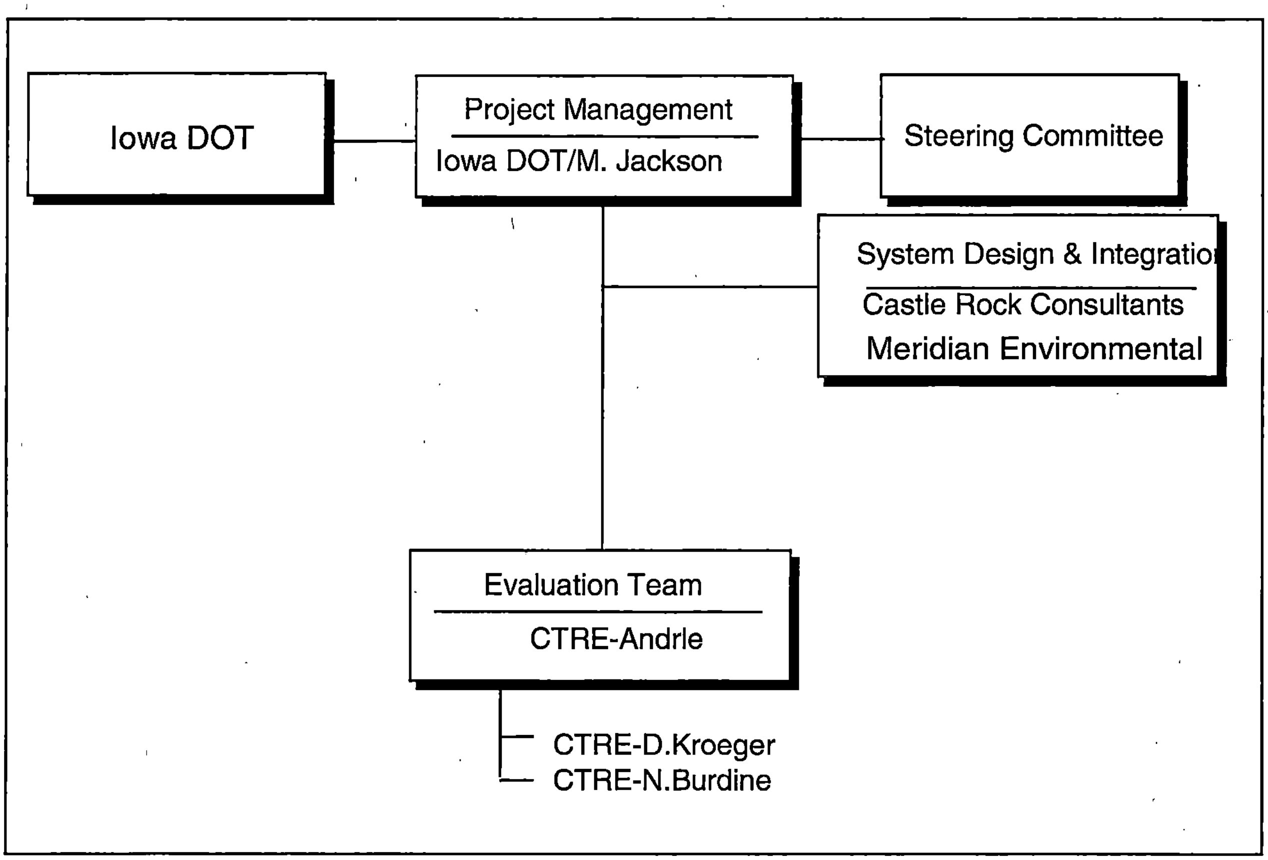


Figure 1.1. General organizational structure

Weather Service Forecasting Operation Goals and Objectives

The primary goal of the Weather Forecasting Service Evaluation project is to verify the accuracy of the forecasts provided to the Iowa DOT. It is anticipated that the project will provide useful information to the Iowa DOT. The objectives developed to support this goal are as follows:

- To improve the efficiency and safety of winter maintenance operations.
- To improve dissemination of weather forecasts and road condition information.
- To increase the performance of the highway system.
- To protect the public investment in our infrastructure.

System Description

The first phase of Weather Forecasting Services Evaluation consisted of the following:

- Developing the existing information system to a network of mainline sites.
- Identifying garages with road weather information systems (RWIS) and ASOS systems nearby.
- Developing the existing database.

A list of the sites is given in Table 1.2, and, the sites are shown on an Iowa map in Figure 1.2.

Table 1.2. Selected garage locations

Garage location	RWIS	ASOS	High speed internet access	Data collection
Altoona	X	X	X	X
Grinnell	X	X	X	X
Newton	X	X	X	X
Hanlontown (Mason City)	X	X	X	X
Waterloo	X	X	X	X
Onawa	X	X	X	X
Sioux City	X	X	X	X
Council Bluffs (South)	X	X	X	X
Missouri Valley	X	X	X	X
Sidney	X	X	X	X
Martensdale	X	X	X	X
Cedar Rapids	X	X	X	X
Davenport	X	X	X	X
Oakdale	X	X	X	X
Tipton	X	X	X	X
Urbana	X	X	X	X

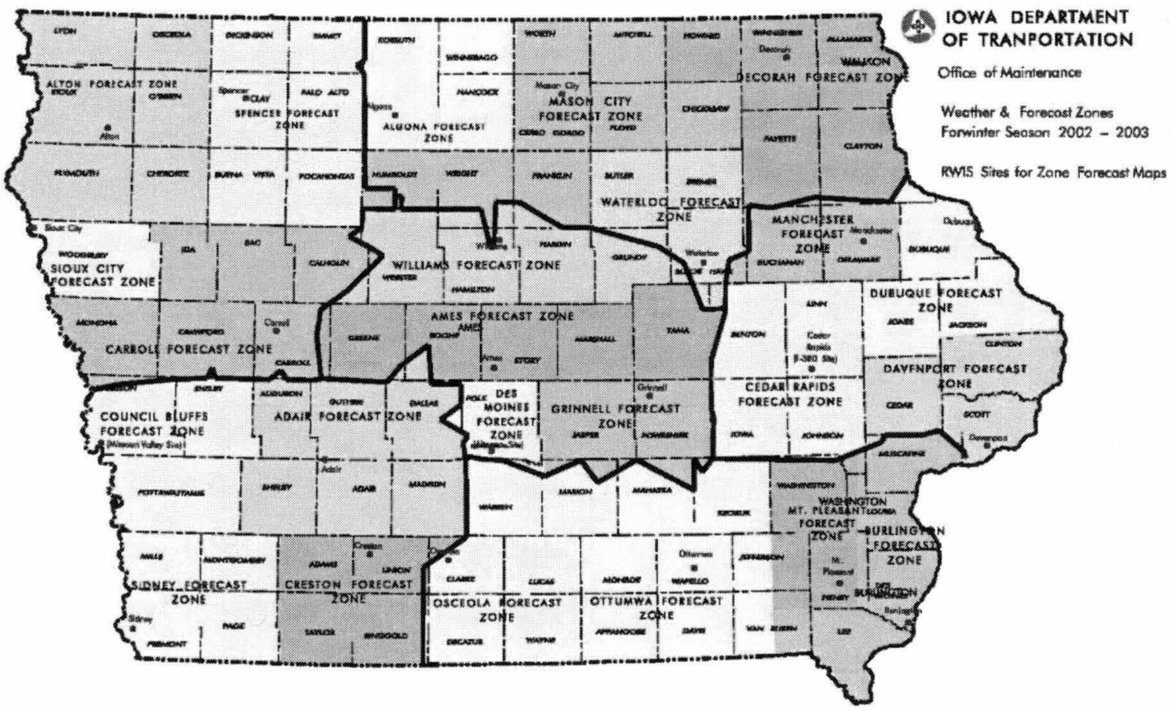


Figure 1.2. Iowa DOT maintenance garage sites in Iowa

Functional Architecture

Figure 1.3 shows schematics for the functional architecture for the RWIS. A more detailed description follows for each of the elements of the Weather Forecasting Service Evaluation Project.

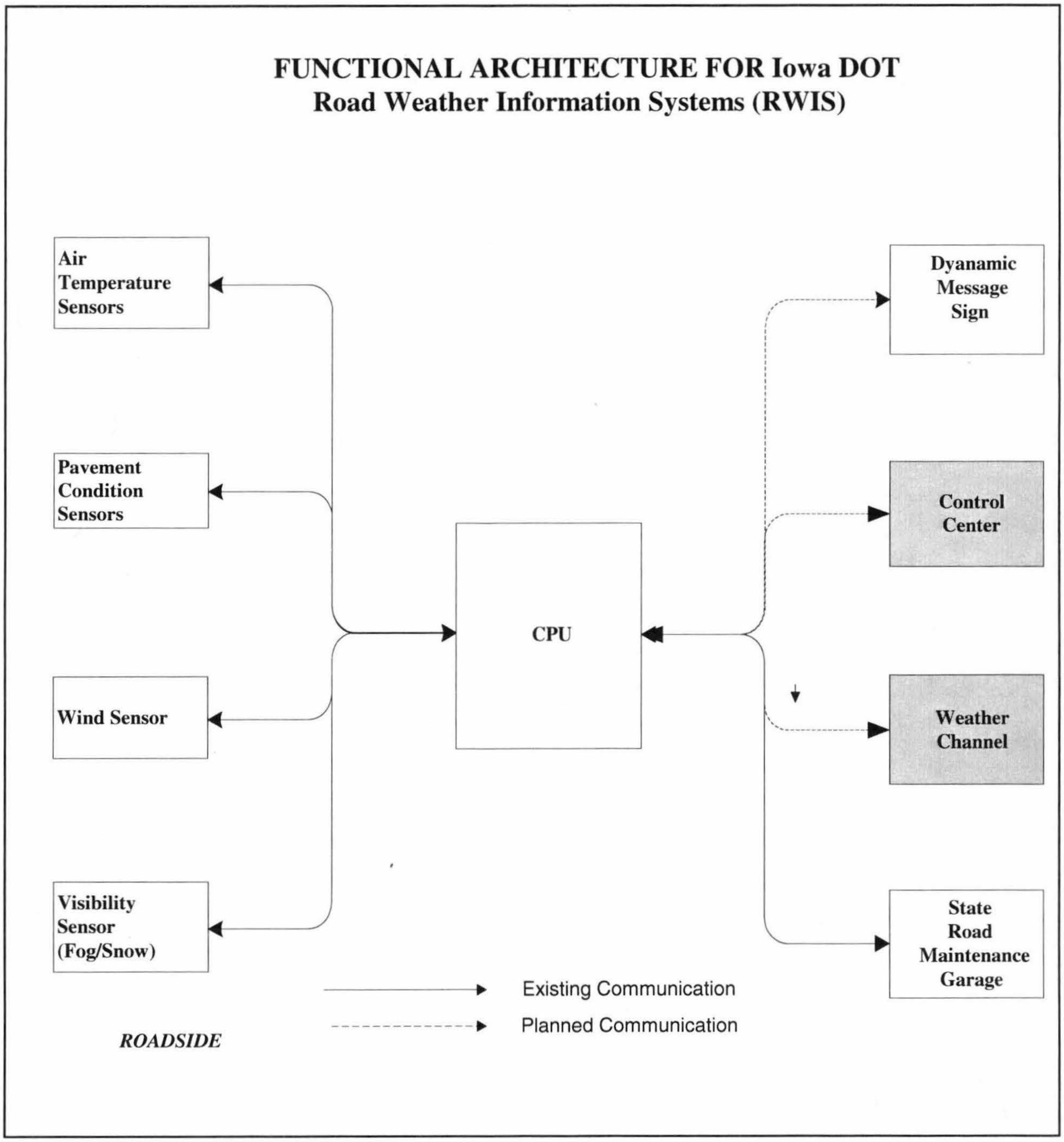


Figure 1.3. Functional architecture for road weather information system

Roadway Weather Information System (RWIS)

The Roadway Weather Information System (RWIS) is a tool focused on safety goals. RWIS can measure air temperature, pavement temperature, subsurface temperature, wind speed, wind direction, dew point, humidity, visibility, and other information needed by transportation managers. Sensors to collect these data are located in and along Iowa's interstate and primary roads. The RWIS network of sensors is designed to provide Iowa DOT Maintenance employees with the specific weather information they need about the roadway. With specific roadway-based weather information, better decisions and treatment strategies for snow and ice control are possible. The Weather Services Forecasting Evaluation Project used the RWIS to provide useful weather information and guidance to maintenance supervisors with specific application to winter maintenance operations.

Project Structure

This report lays out the framework that is being followed in conducting the Weather Services Forecasting project technical evaluation. This report is organized into the following three chapters:

Chapter 1: **Introduction and Project Plan**. Provides general information on the purpose, partnership, and organization of the operational test, defines the test goals and objectives and their relation to the national goals, and supplies a general system description.

Chapter 2: **Evaluation Design**. Provides the evaluation approach including the evaluation goals, objectives, and measures; and defines the technical approach.

Chapter 3: **Detailed Research**. Describes the methodology of the research.

Chapter 4: **Summary and Conclusions**. Provides the findings of the evaluation research.

2. EVALUATION DESIGN

As noted in Chapter 1, the primary purpose of the Weather Forecasting Services Evaluation project is to verify the accuracy of the weather forecast information and road condition information and to improve the efficiency and safety of winter maintenance operations, increase performance of the highway system, and to protect the public investment in our infrastructure. These evaluations help support further development of technology deployments, public sector policy development, private sector product/service development, and decisions to continue, modify, or suspend operational technology deployments. The purpose of this evaluation is to assess the benefits and impacts (positive and negative) of the weather forecasting systems and services presently being utilized by the Iowa DOT. Within this context, Chapter 2 outlines the evaluation goals and objectives adopted by the Weather Forecasting Services evaluation measures, evaluation technical approach, and test activity description.

Evaluation Goals And Objectives

The Weather Forecasting Services proposal contained a preliminary set of evaluation goals. On November 20, 2002, a meeting of the evaluation team resulted in an updated set of goals, and subsequently, a sub-group of the evaluation team developed a set of revised goals and objectives. The following three goals were finally recommended to guide the evaluation:

Goal #1: Assess Accuracy
Goal #2: Assess Productivity
Goal #3: Assess User Acceptance

For the Weather Forecasting Services Evaluation project, objectives have been developed in support of each of the evaluation goals outlined above. These will be addressed in the next section. Each objective is has a high priority. High priority objectives that will be emphasized in evaluation data collection and analysis activities address the questions most fundamental to the ultimate users for the technology and services being tested: "Does the system improve safety?," "Does the system improve productivity?," "Are the procedures developed accepted by system users?," and "What are the key organizational, regulatory, and other challenges that need to be overcome?"

Evaluation Measures

A formal, repeatable, and supportable research technique will be used to conduct the technical evaluation. This technique begins with the development of the basic items of information that, for the purposes of this evaluation, are generally called "evaluation measures" (in technical literature, these measures are frequently referred to as "measures of effectiveness" [MOEs], "measures of performance" [MOPs], and "measures of suitability" [MOSs]). Evaluation measures are quantifiable or measurable parameters that validate the intended impacts or physical functions required of the object/feature being tested, or, alternatively, the intended capability of the object/feature to be deployed and used in realistic environment. Each evaluation objective is linked to one or more evaluation measures as shown in Table 2.1. These measures form the bases for hypotheses statements.

Table 2.1. Measures supporting evaluation goals and objectives

Goal	Objective	Measure
1. Assess Accuracy of Forecasting Services	1.1 Determine changes in daily forecasts	1.1.1 Comparison of forecasted precipitation and actual recorded precipitation by RWIS/ASOS/AWOS
	1.2 Determine differences between forecasts and Road Weather Information System (RWIS), and AWOS/ASOS observations.	1.2.1 Comparison of forecasted air and pavement temperatures to actual recorded air and pavement temperatures by RWIS/AWOS/ASOS
2. Assess Productivity	2.1 Determine timeliness of forecasts	2.1.1 Comparison of the time of the forecasted event to when weather event actually materialized.
	2.2 Determine any changes in forecasts during events.	2.2.1 Compare total forecasts made by weather services (predicting events and predicting non events).
		2.2.2 Compare number of "false alarms"
3. Assess User Acceptance	3.1 Assess Maintenance Garage Acceptance	3.1.1 Attitude towards weather forecast service including perceived impacts.
		3.1.2 Attitude towards new services, e.g., did forecasts provide timely information?
	3.2 Assess Agency Acceptance	3.2.1 Attitude towards weather forecasting services, including perceived impacts.
		3.2.2 Attitude towards new services, e.g.: Did selected forecasting services provide needed information for decision support services?

Evaluation Technical Approach

Given the evaluation measures defined, it is possible to determine what types of individual tests are needed to obtain this information and when these tests should be performed within the overall evaluation schedule. Individual tests are the means through which operational test evaluation data are obtained. Data needs are grouped by the venue in which the data are collected. The purpose of developing separate (i.e., individual) tests is to coherently organize the data collection process in a manner that will do the following:

1. Support differences in evaluation planning and design needed to accommodate differences among venues,

2. Economize on project resources by combining the data collection effort associated with each venue, and
3. Minimize respondent burden by reducing the number of separate data requests of evaluation participants.

Data Collection Methodologies

Four individual data collection methods were identified as potential data for collection methodologies for the Weather Forecasting Services project. Briefly, these are as follows:

- **System Records**. Operational data were gathered daily from the FORETELL database and the Meridian database for the 16 garage sites.

  FORETELL sent forecasts to CTRE four times per day and these forecasts were stored for analysis. We received forecasts from FORETELL via email for the forecasts issued at 03:00, 09:00, 15:00, and 21:00 (CST).

  Meridian's daily forecasts are stored on its server and CTRE retrieved them, daily, for each of the garage sites selected. Meridian issues its forecasts three times per day at 04:00, 12:00, and 20:00 (CST). Additional information is transmitted if weather conditions require (e.g., precipitation changes in form or amount). Furthermore, on some days, numerous forecasts were issued by the weather services as weather conditions changed. Additional weather information was also used in our analysis.

- **User Surveys/Information Requests**. CTRE developed a web-based data collection form to collect operational and observation data from each of the garages. The garage supervisor can access the weather reporting form at http://www.ctre.iastate.edu/weatherreport.

- **User Interviews**. CTRE interviewed the garages on the usefulness of the weather forecasts and which forecasts provided more useful information in their maintenance decision process.

- **Observation**. CTRE used RWIS, ASOS, and AWOS systems to determine start times and end times of weather events as well as precipitation amounts.

Many evaluation factors are complex in that a number of pieces of test data must be collected to support calculating the required measure. The data types critical to the evaluation and their sources, including what information will be automatically collected directly from the system, through surveys and logs, and through observation and interviews, are cataloged and archived throughout the evaluation.

Analysis Methodologies

All Weather Forecasting Services quantitative evaluation data (including data obtained through surveys, interviews, log keeping, and system record selection) were analyzed. The purpose of statistically analyzing quantitative data is to assess the degree to which the data are representative of the population being tested and to determine whether the conclusions drawn from the data are valid. It is recognized that, due to the sample size and selection criteria, the weather event sample population may not be representative of the weather event population as a whole.

The data were collected in the following manner:

1. Start time of event—forecast vs. observed
2. End time of event—forecast vs. observed
3. Pavement temperature—forecast vs. observed
4. Accumulation of precipitation—forecast vs. observed
5. Type of precipitation—forecast vs. observed
6. What forecast sources were used to make operational decision?

Of course, all statistical analyses techniques are subject to error. These errors are generally categorized as sampling and non-sampling errors. Sampling errors are those that may occur because the whole population is not included in the test, while non-sampling errors are those that may occur at any stage in a research project due to mistakes in data collection, manipulation, or analysis. The Weather Forecasting Services evaluation attempted to control for such errors to the greatest extent possible within the given resource constraints.

3. DETAILED RESEARCH

We collected storm data from the garages, Foretell and Meridian Environmental, from December 1, 2002 to March 31, 2003. We identified twenty-seven snow events across the state, where some type of precipitation impacted a garage site. These dates are

December 2, 3, 11, 17, 20, 2002
January 4, 5, 13, 14, 18, 27, 28, 31 2003
February 3, 4, 9, 10, 14, 15, 22, 23, 28 2003
March 3, 4, 5, 6, 8, 2003

Data Sets

Multiple sets of observational data were used to evaluate the Foretell and Meridian Forecast outputs. One set of information used was reports received from the selected maintenance garages across Iowa. The data elements from the garage reports that were used for comparisons included date of event, beginning and ending time of event, type of precipitation observed, and precipitation amount observed. Some garages did not submit reports, and were excluded from all comparisons.

If ASOS/AWOS stations are located in the same vicinity as the maintenance garage, hourly ASOS/AWOS data were collected during the evaluation period from Iowa Environmental Mesonet (see Table 3.1). Data used from ASOS stations included time and type of precipitation. The Preliminary Local Climatological Data issued by the NWS were used where possible to compare forecasted liquid equivalent and snow amounts to the observed data. The climatological data reports the liquid equivalent and snow amounts on daily basis. We assumed that the entire amount of precipitation that was reported occurred during the timing of the event reported from the garages. The Iowa Environmental Mesonet supplied hourly pavement temperatures for sites where RWIS stations were in close proximity of the evaluation site (see Table 3.1).

Table 3.1. Data available for comparisons

	Garage data	RWIS air	RWIS pavement	ASOS/AWOS data	NWS precipitation amounts
Altoona	Yes	Yes	Yes	Yes	Yes
Cedar Rapids	Yes	Yes	Yes	Yes	Yes
Council Bluffs	Yes	Yes	Yes	Yes	Yes
Davenport	Yes	Yes	Yes	Yes	Yes
Martensdale	Yes	No	No	Yes	Yes
Missouri Valley	Yes	Yes	Yes	No	Yes
Newton	Yes	No	No	No	No
Oakdale	Yes	No	Yes	Yes	Yes
Sidney	Yes	Yes	Yes	No	No
Sioux City	Yes	No	No	Yes	Yes
Tipton	Yes	Yes	Yes	Yes	Yes
Urbana	Yes	Yes	Yes	Yes	Yes
Waterloo	Yes	Yes	Yes	Yes	Yes

Garage Event Timing Comparisons

Garage Event Timing evaluated the accuracy of the forecast's prediction of the beginning and ending time of garage precipitation events. Researchers classified garage events as a time period when a maintenance garage reported precipitation that may require actions by the garage maintenance crew. Beginning and ending times according to garage reports of events were used as observed times for comparison to the Foretell and Meridian outputs. Three comparisons were done with event timing, Foretell and Meridian Now Cast Comparison, Foretell and Meridian 12 Hour Forecast Comparison, and Foretell 24 Hour Forecast Comparison. Cast Comparisons were done using the latest forecast output before the event occurred. The 12 Hour Forecast Comparisons used the forecast output issued at least 12 hours before the start of an event. Forecasts issued 24 hours or more before the start of an event were used for the 24 Hour Forecast Comparisons. Differences in starting and ending times were determined along with averages and standard deviations.

If the forecast output used for a comparison had precipitation occurring at the end of the forecast run, the next run, or if necessary, next few runs, were used to determine the end time of an event.

Some forecast runs were not available for evaluation. If the forecast run output needed for a specific comparison was not available the event was not evaluated. For example, if the 3:00 GMT forecast output was needed for a 12 Hour Forecast Comparison but it was not in the database, the event was not evaluated.

Table 3.2 describes the output of the garage event timing comparisons. The table shows the predicted start times from the weather services for all events from all the reporting garages. The table shows that there were 118 forecast start times from the Meridian service, with 19 precipitation event start times with precipitation not forecasted. The table further shows that there were 61 forecasted start times from the Foretell service with 76 storm event start times with precipitation not forecasted. The N* indicates that the model run was missing, or that the forecast just prior to the event indicated no precipitation predicted. The mean difference in the predicted start time for a precipitation event from the Meridian service is 107.8 minutes. The mean difference in the predicted start time for a precipitation event from the Foretell services is 176.9 minutes.

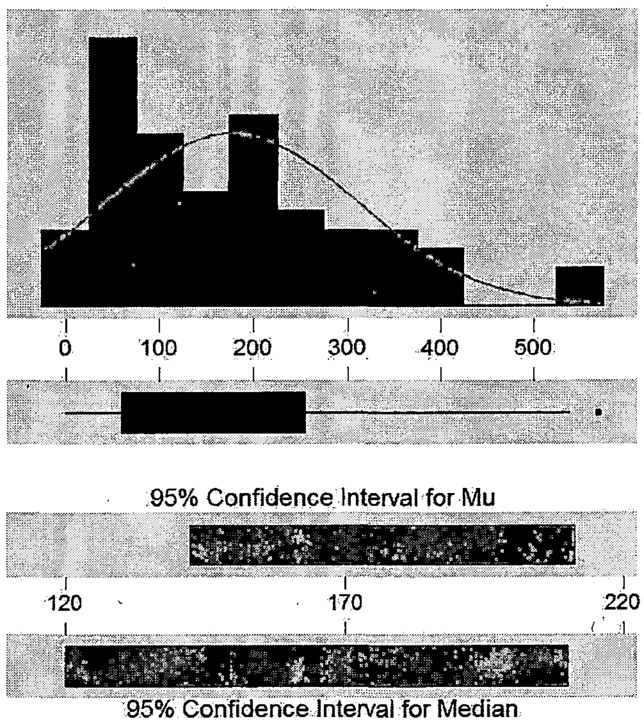
Table 3.2. Descriptive statistics: Meridian difference, Foretell difference

Variable	N	N*	Mean	Median	TrMean[i]	St. Dev	SE Mean	Min.	Max.	Q1	Q3
Meridian	118	19	107.8	72.5	93.8	123.1	11.3	0.0	1005.0	30.0	123.8
Foretell	61	76	176.9	150.0	168.3	134.3	17.2	0.0	570.0	60.0	255.0

* Precipitation was not forecasted start time of event.

Figure 3.1 depicts the descriptive statistics. The figure shows the mean differences that were calculated from all the start times forecasted by Foretell for all garages in the study. Based on 61 observations, the figure depicts a mean difference of 176.869 minutes with a 95 confidence interval.

Descriptive Statistics



Variable: Foretell Dif

Anderson-Darling Normality Test

A-Squared:	1.169
P-Value:	0.004
Mean	176.869
StDev	134.335
Variance	18045.8
Skewness	0.894932
Kurtosis	0.444793
N	61
Minimum	0.000
1st Quartile	60.000
Median	150.000
3rd Quartile	255.000
Maximum	570.000

95% Confidence Interval for Mu

142.464	211.274

95% Confidence Interval for Sigma

114.011	163.544

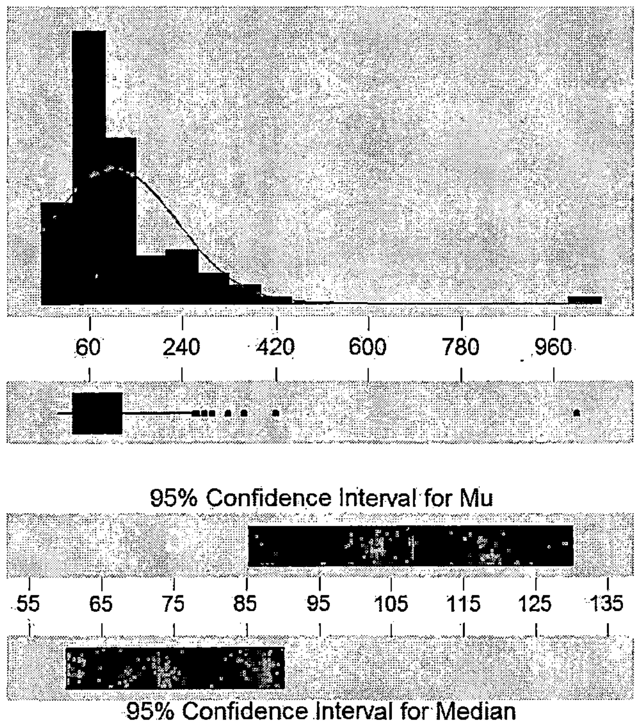
95% Confidence Interval for Median

120.000	210.000

Figure 3.1. Precipitation start time differences from Foretell

Figure 3.2 depicts the descriptive statistics from Table 3.2 for the forecasted start times from the Meridian service. Based on 118 observations, the figure depicts a mean precipitation start time difference of 107.771 minutes with a 95 percent confidence interval.

Descriptive Statistics



Variable: Meridian Dif

Anderson-Darling Normality Test

A-Squared:	7.163
P-Value:	0.000
Mean	107.771
StDev	123.079
Variance	15148.3
Skewness	3.79814
Kurtosis	23.5232
N	118
Minimum	0.00
1st Quartile	30.00
Median	72.50
3rd Quartile	123.75
Maximum	1005.00

95% Confidence Interval for Mu

85.33 130.21

95% Confidence Interval for Sigma

109.13 141.15

95% Confidence Interval for Median

60.00 90.00

Figure 3.2. Precipitation start time differences from Meridian

Table 3.3 describes the output of the garage event timing comparisons for the predicted ending times of the precipitation events. The table shows the number of predicted ending times from the weather services for all events from all the reporting garages. The table shows that there were 118 forecast ending times from the Meridian service, with 19 storm event end times not forecasted. The table further shows that there were 60 forecasted ending times from the Foretell service with 77 event ending times not forecasted. The N* indicates that the forecast model run just prior to the event indicated no precipitation predicted. The mean difference in the predicted ending time for a precipitation event from the Meridian service is 177.1 minutes. The mean difference in the predicted end time for an event from the Foretell services is 266.6 minutes.

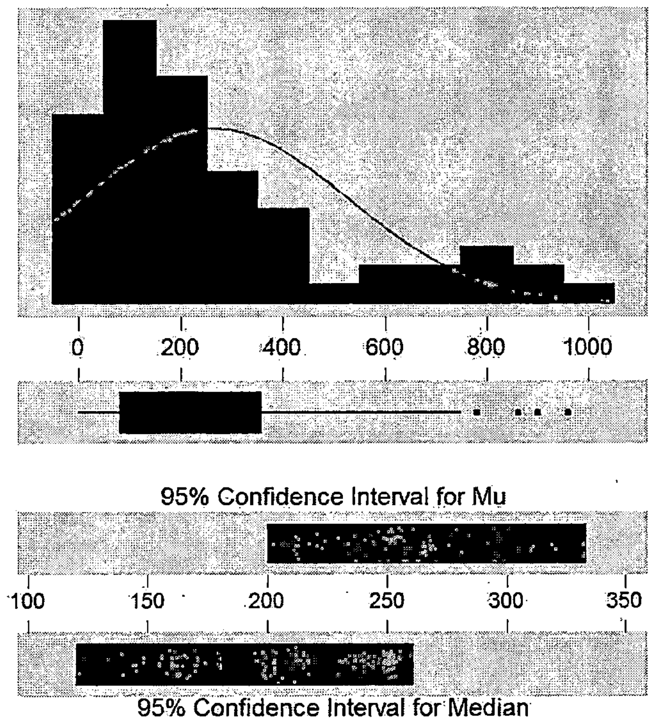
Table 3.3. Precipitation End Times : Meridian difference, Foretell difference

Variable	N	N*	Mean	Median	TrMean**	St. Dev	SE Mean	Min.	Max.	Q1	Q3
Meridian	118	19	177.1	124.5	155.6	173.0	15.9	0.0	880.0	60.0	240.0
Foretell	60	77	266.6	180.0	245.9	258.0	33.3	0.0	960.0	82.5	357.5

* End time of events not forecasted. ** TrMean is a trimmed mean, which removes 5% of the smallest values and 5% of the largest values, and then reports the average of the remaining values.

Figure 3.3 depicts the descriptive statistics from Table 3.3 for the forecasted storm ending times from Foretell's forecasts. Based on 60 observations, the figure depicts a mean event end time difference of 266.633 minutes with a 95 percent confidence interval.

Descriptive Statistics



Variable: Foretell Dif

Anderson-Darling Normality Test

A-Squared:	3.226
P-Value:	0.000
Mean	266.633
StDev	257.963
Variance	66545.0
Skewness	1.23070
Kurtosis	0.569386
N	60
Minimum	0.000
1st Quartile	82.500
Median	180.000
3rd Quartile	357.500
Maximum	960.000

95% Confidence Interval for Mu

199.994	333.272

95% Confidence Interval for Sigma

218.658	314.628

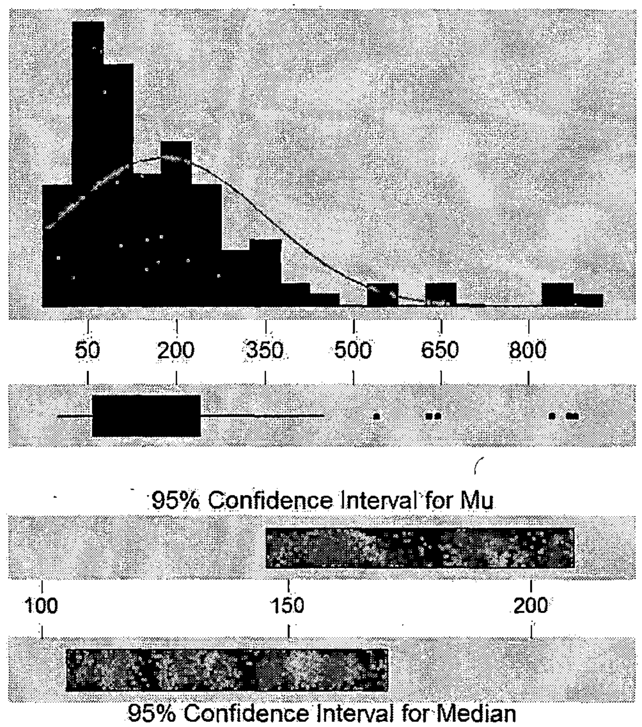
95% Confidence Interval for Median

120.000	260.693

Figure 3.3. Precipitation end time differences from Foretell

Figure 3.4 depicts the descriptive statistics from Table 3.3 for the forecasted precipitation ending times from Meridian's forecasts. Based on 118 observations, the figure depicts a mean event end time difference of 177.102 minutes with a 95 percent confidence interval.

Descriptive Statistics



Variable: Meridian Dif

Anderson-Darling Normality Test

A-Squared:	6.203
P-Value:	0.000
Mean	177.102
StDev	173.048
Variance	29945.5
Skewness	2.08278
Kurtosis	5.24995
N	118
Minimum	0.000
1st Quartile	60.000
Median	124.500
3rd Quartile	240.000
Maximum	880.000

95% Confidence Interval for Mu

145.553 208.651

95% Confidence Interval for Sigma

153.432 198.460

95% Confidence Interval for Median

104.917 170.368

Figure 3.4. Storm end time differences from Meridian

False Alarms

False Alarms were determined by comparing all forecasted precipitation to observed ASOS precipitation. If precipitation was forecasted for two or more consecutive hours, and no precipitation was observed 12 hours before or after that time, it was considered a false alarm. False alarms for Foretell were divided into three groups: 15 hours or less, greater than 15 hours, and total false alarms, in order to capture the model runs. For example, if Foretell forecasted precipitation 5 hours from the beginning of the forecast run, it went into the 15 hours or less false alarm group. Total false alarms only included an event once if it occurred in the 15 hours or less and greater than 15 hours. Table 3.4 describes the number of storm events forecasted by each service and the number of events reported by the garages. Table 3.5 shows the false alarm rate (FAR) for each location. The false alarm rate is computed as the number of false alarms divided by the number of false alarms plus hits, depicted as

$$FAR = \frac{\text{False Alarms}}{\text{False Alarms} + \text{hits}}$$

A 0.00 rate is considered best.

Table 3.4. Number of storm events by location

City	Number of ASOS events	Number of garage events	Number of garage events evaluated for Meridian	Number of garage events evaluated for Foretell
Altoona	31	14	14	11
Cedar Rapids	32	11	11	9
Council Bluffs	28	9	9	8
Davenport	29	17	17	16
Martensdale	31	19	19	17
Missouri Valley	NA	9	9	9
Newton	NA	4	4	4
Oakdale	26	3	3	3
Sidney	NA	4	4	4
Sioux City	31	1	1	1
Tipton	27	18	18	18
Urbana	23	16	16	16
Waterloo	23	8	8	8

Table 3.5. False alarm rates

City	Meridian	Foretell	Foretell <15 hours	Foretell > 15 hours	Meridian FAR	Foretell FAR
Altoona	11	8	5	6	0.27	0.31
Cedar Rapids	13	9	4	8	0.33	0.33
Council Bluffs	17	13	9	7	0.39	0.43
Davenport	22	17	7	15	0.45	0.61
Martensdale	11	17	10	15	0.28	0.44
Missouri Valley	NA	NA	NA	NA	NA	NA
Newton	NA	NA	NA	NA	NA	NA
Oakdale	25	15	8	14	0.51	0.48
Sidney	NA	NA	NA	NA	NA	NA
Sioux City	18	13	7	11	0.40	0.43
Tipton	25	14	6	12	0.52	0.47
Urbana	20	11	9	3	0.50	0.42
Waterloo	24	13	8	10	0.52	0.43
Average	**18.60**	**13.00**	**7.30**	**10.10**	**0.42**	**0.44**
Standard deviation	**5.52**	**3.02**	**1.89**	**4.07**	**0.10**	**0.08**

The False Alarm Rate for Meridian was 0.42 and for Foretell was 0.44 compared to the ASOS systems. The 15 hour time frame was used in determining the false alarm rate in order to capture both services forecast runs. The Foretell service predicts weather conditions up to 30 hours ahead and the Meridian service predicts weather conditions up to 24 hours. We determined that by using plus or minus 15 hours we would capture both models' predictions for precipitation.

Garage Event Timing Comparisons Using ASOS Data

Garage Event Timing Comparisons were done using events as previously classified. Where possible, the beginning and ending times of garage events were determined using nearby ASOS stations. These times were then compared to forecast outputs for Now Cast Comparisons.

ASOS Events

ASOS Events were classified anytime that an ASOS station reported precipitation for more than an hour during the evaluation period. To be classified as an event, precipitation had to be measurable. Light precipitation such as mist and haze were not considered precipitation for the purposes of this evaluation.

ASOS Event Hits

ASOS events were compared to forecast output to determine the probability of the forecast detecting any precipitation observed. If any precipitation was forecasted within 12 hours before or after an ASOS event, it was considered an ASOS event hit.

Table 3.6 shows the predicted hits from each of the weather forecasting services. The table shows the hits as compared to the ASOS system and the garage reports. The table indicates that Meridian agreed with the ASOS system 0.91 or 91 percent of the time. Foretell agreed with the ASOS system 0.60 or 60 percent of the time. Furthermore, the data show that Meridian agreed with the garage reports at an average of 90 percent, while the Foretell agreed with the garage reports at an average of 54 percent.

Table 3.6. Forecast hit rate

City	ASOS Event Hits				Garage Event Hits %			
	Meridian hits	Foretell hits	Meridian %	Foretell %	Meridian hits	Foretell hits	Meridian %	Foretell %
Altoona	30	18	0.97	0.58	11	5	0.79	0.45
Cedar Rapids	27	18	0.84	0.56	11	6	1.00	0.67
Council Bluffs	27	17	0.96	0.61	8	2	0.89	0.25
Davenport	27	11	0.93	0.38	15	8	0.88	0.50
Martensdale	29	22	0.94	0.71	17	9	0.89	0.53
Missouri Valley	NA	NA	NA	NA	8	4	0.89	0.44
Newton	NA	NA	NA	NA	4	2	1.00	0.50
Oakdale	24	16	0.89	0.62	3	2	1.00	0.67
Sidney	NA	NA	NA	NA	3	2	0.75	0.50
Sioux City	27	17	0.84	0.55	1	1	1.00	1.00
Tipton	23	16	0.85	0.59	14	8	0.78	0.44
Urbana	20	15	0.87	0.65	16	8	1.00	0.50
Waterloo	22	17	0.96	0.74	7	4	0.88	0.50
Average			**0.91**	**0.60**			**0.90**	**0.54**
Standard deviation			**0.05**	**0.10**			**0.09**	**0.17**

Precipitation Comparisons

Liquid Equivalent Amounts

Liquid equivalent forecast amounts were compared to the available Preliminary Local Climatological Data from the NWS. The Meridian and Foretell forecasted liquid precipitation amounts were compared to observed data for all three sources. Precipitation during an event was assumed to account for all precipitation reported by the climate report for the day in question. If precipitation was forecasted through the end of the forecast output period, the follow up forecast runs were used to determine the liquid forecasted amount.

Snow Amounts

Snowfall amounts for Meridian for the Now Cast and 12 Hour Comparisons output were compared to both garage and NWS snow observations. Foretell snowfall amounts were not reported because Foretell reports liquid equivalent precipitation, therefore no comparisons were made to it. If precipitation was forecasted through the end of the forecast output period, the follow up forecast runs were used to determine the snowfall amount. Climate report amounts were compared to forecast amounts on the assumption that all of the snow reported in the climate data was due to snowfall during the garage event. Average differences for both garage and NWS observations were computed.

Precipitation Type

Meridian and Foretell precipitation type outputs for the three associated categories were compared to the garages and ASOS stations' reported precipitation type. A garage precipitation type hit was classified as a hit when the forecast output projected the type of precipitation observed by the garage during the event time. For example, if the forecast predicted mixed rain and snow, but only snow was observed, it was classified as a hit. Precipitation hit percentages were calculated using the amount of correctly identified precipitation events, and the number of events evaluated for that forecast. Some events were not evaluated due to missing forecast data.

Precipitation type comparisons were also prepared for ASOS events. If any forecast run predicted the type of precipitation observed by the ASOS during an event, that forecast run was considered a hit. These forecast runs were considered a hit even if the types of precipitation that were forecasted during a different forecast run, did not match perfectly (e.g., rain, snow, or mix).

Table 3.7 states that the snowfall amounts for all garages were underreported by an average of 0.46 inches, comparing to observed amounts. The National Weather Service snowfall amount difference was an average 0.16, as compared to observed data at the garages.

Table 3.7. Precipitation comparisons for Meridian

Meridian			**Meridian-Actual**	**Meridian-Actual**	**Meridian-Actual**
City	**Number of garage events evaluated**	**Number of ASOS events evaluated**	**Liquid amount Average difference**	**Garage snow amount average difference**	**NWS snow amount Average difference**
Altoona	14	31	-0.09	-0.28	-0.12
Cedar Rapids	11	32	0.01	-0.09	0.15
Council Bluffs	9	28	-0.01	-0.82	-0.42
Davenport	17	29	0.03	0.16	0.31
Martensdale	19	31	0.01	0.00	0
Missouri Valley	9	NA	-0.03	-0.23	-0.77
Newton	4	NA	NA	-2.38	NA
Oakdale	3	27	0.09	0.74	0.83
Sidney	4	NA	NA	-0.42	NA
Sioux City	1	32	-0.32	-2.20	-1.5
Tipton	18	27	0.01	-0.28	-0.17
Urbana	16	23	0.02	0.06	0.08
Waterloo	8	23	-0.02	-0.21	-0.19
Average			**-0.03**	**-0.46**	**-0.16**
Standard deviation			**0.11**	**0.89**	**0.60**

Table 3.8 describes the liquid equivalent amounts of precipitation as reported by Foretell. The data show that Foretell over reported the liquid equivalent amounts by an average of 0.05 inches, compared to the ASOS reports.

Table 3.8. Precipitation comparisons for Foretell

Foretell			Model-Actual
City	Number of garage events evaluated	Number of ASOS events evaluated	Liquid amount average difference
Altoona	11	31	-0.39
Cedar Rapids	9	32	0.04
Council Bluffs	8	28	0
Davenport	16	29	-0.02
Martensdale	17	31	-0.06
Missouri Valley	9	NA	-0.13
Newton	4	NA	NA
Oakdale	3	26	0.26
Sidney	4	NA	NA
Sioux City	1	31	0.85
Tipton	18	27	-0.05
Urbana	16	23	0.08
Waterloo	8	23	-0.07
Average			**0.05**
Standard deviation			**0.31**

Temperature Comparisons

To determine the accuracy of the forecasts' forecasted pavement temperatures, the output closest to the time of the event was compared to observed RWIS data. RWIS station's hourly data located near forecast points were compared to forecast output during garage event times. Not all event hours could be compared due to either missing RWIS or forecast output data.

Table 3.9 shows an average pavement temperature difference of 2.46 degrees Fahrenheit for all locations. This is determined by taking the Meridian reported pavement temperature just prior to the start of a predicted storm event and comparing it to the RWIS reported pavement temperature at the same time. The data also show that the Meridian pavement temperatures are reporting an average of 0.76 degrees Fahrenheit colder than the RWIS sensors.

Table 3.9. Meridian pavement temperature differences by garage

Meridian City	Meridian observed Pave temp bias	Meridian observed Pave temp dif. average
Altoona	-1.4	2.5
Cedar Rapids	0.5	2.2
Council Bluffs	-0.8	3.4
Davenport	-0.8	2.7
Martensdale	NA	NA
Missouri Valley	-2.9	3.2
Newton	NA	NA
Oakdale	-1.0	2.3
Sidney	1.6	1.7
Sioux City	NA	NA
Tipton	-1.0	2.6
Urbana	-0.6	2.3
Waterloo	-1.3	1.6
Average	-0.76	2.46
Standard Deviation	1.19	0.58

Table 3.10 shows an average pavement temperature difference of 5.86 degrees Fahrenheit for all locations. This is determined by obtaining the reported Foretell pavement temperature, just prior to the predicted start of the storm event, and comparing it to the RWIS reported pavement temperature at the same time. The data also show that the Foretell pavement temperatures are reporting an average 0.33 degrees warmer than the sensors.

Table 3.10. Foretell pavement temperature differences by garage

Foretell	Foretell Observed	Foretell Observed
City	**Pave temp bias**	**Pave temp dif. Average**
Altoona	-1.6	4.5
Cedar Rapids	6.6	8.3
Council Bluffs	-4.3	7.7
Davenport	0.3	5.6
Martensdale	NA	NA
Missouri Valley	-6.4	8.1
Newton	NA	NA
Oakdale	3.0	4.3
Sidney	-1.0	3.4
Sioux City	NA	NA
Tipton	2.0	6.7
Urbana	3.4	6.7
Waterloo	1.3	3.5
Average	**0.33**	**5.86**
Standard Deviation	**3.82**	**1.88**

A regression analysis was performed on the pavement temperature data. The figures on the following pages describe the analysis and include data from all reporting locations.

The analysis in Figure 3.5 is based on 693 total observations from all the Meridian forecast reports for the duration of the evaluation. The analysis compares the reported pavement temperatures from Meridian to the observed pavement temperature from the RWIS output nearest to the garage. The R-Sq for this comparison is 88.7%.

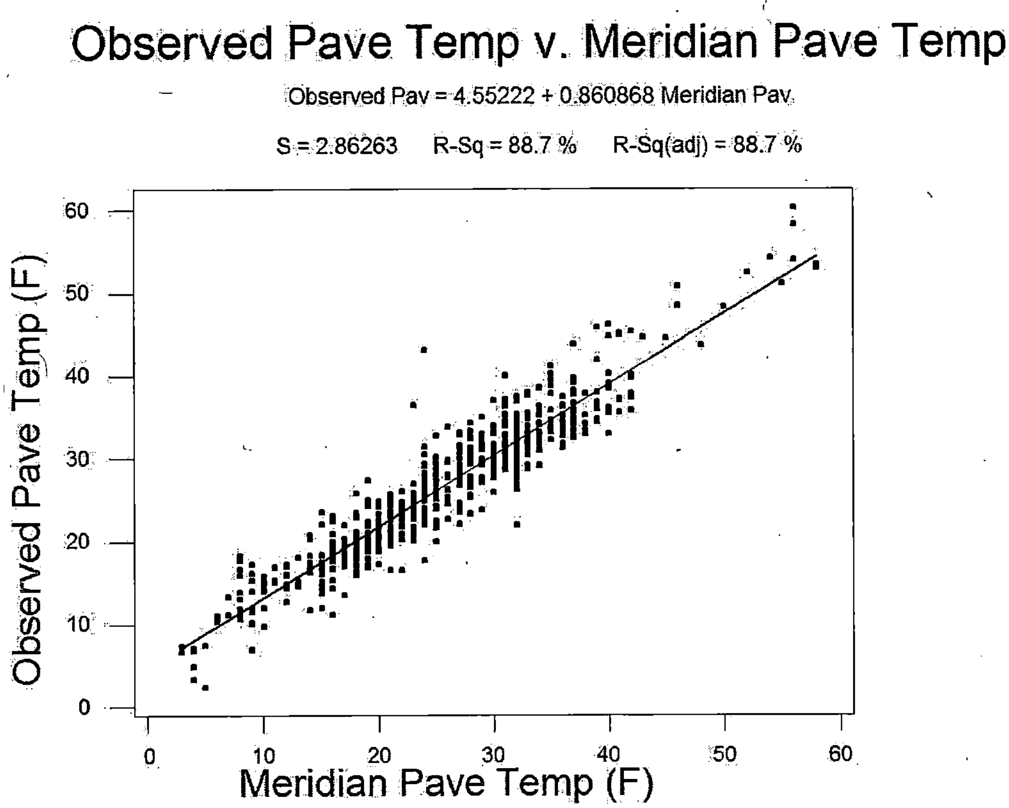


Figure 3.5. Regression analysis forecasted Meridian pavement temperatures to observed pavement temperatures

The analysis in Figure 3.6 is based on 608 total observations from all the Foretell forecast for the duration of the evaluation. The analysis compares the reported pavement temperatures from Foretell to the observed pavement temperature from the RWIS output nearest to the garage. The R-Sq for this comparison is 53.7 %.

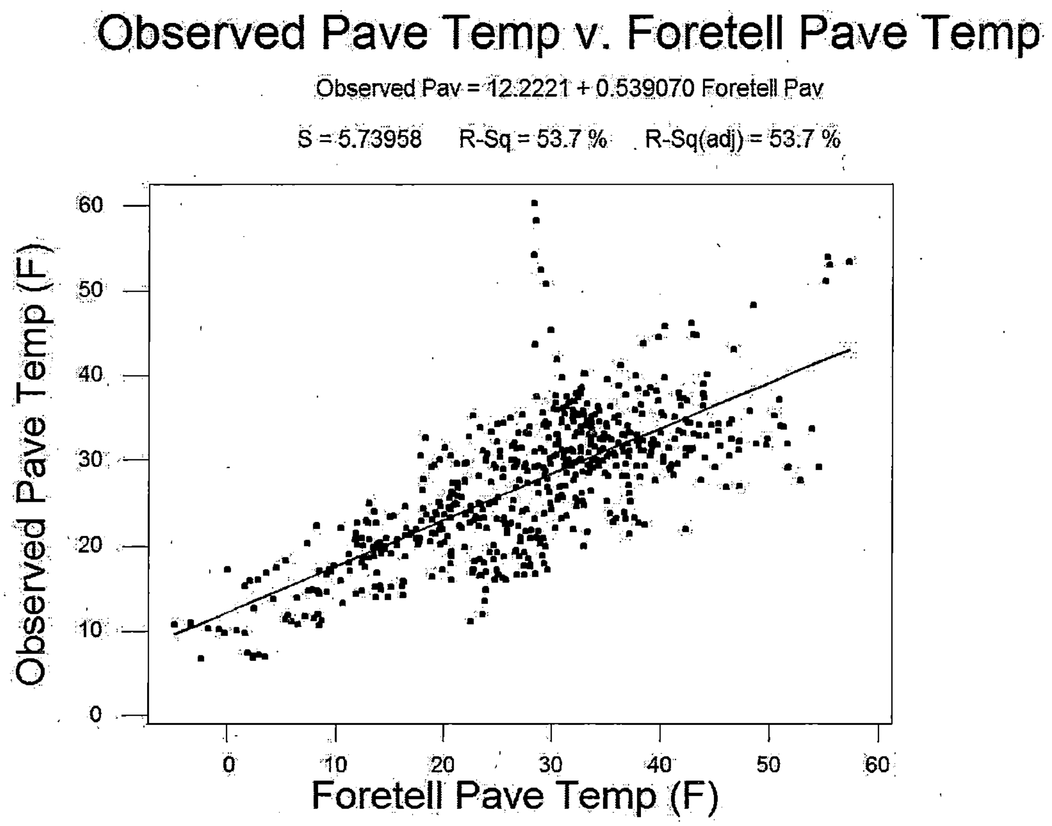


Figure 3.6. Regression analysis: Foretell predicted temperatures to observed pavement temperatures

Appendix B includes regression analyses for each of the reporting garages.

User Acceptance

For the collection of garage weather data, we developed a web-based questionnaire. The questionnaire is on our website (www.ctre.iastate.edu/weatherreport). The questionnaire has been useful and the garages are submitting their observations following each storm event. For the duration of the evaluation, ending March 31, 2003, we received a total of 192 web-based reports from the garages, indicating the impact of the weather at their specific location. The web-based reporting system worked effectively. Following a storm event, an email message was sent to the garages reminding them to report any event. The garages responded quickly to the email messages, and many reported without the reminder.

Following the winter season, we also surveyed the garage personnel to determine their satisfaction with the weather forecasting services. Of the sixteen garages we surveyed, we received seven replies from the questionnaire. While the response rate was not what we hoped it would be, the responses that we did receive provide some insight to how the garages view the weather information that they receive.

The following is the survey that we administered and summaries of the responses that we received.

1. We use Foretell prior to each storm. Agree or Disagree

    4 agreed 3 disagreed

2. If you answered disagree, please explain briefly.

    Most of the events this year were small amounts of snow.

    I personally do not use Foretell before every storm but my assistant does.

    We do not use Foretell prior to each storm as we use the local and DTN for our forecast as they are usually more accurate and up-to-date.

3. We use Meridian prior to each storm. Agree or Disagree

    4 agreed 3 disagreed

4. If you answered disagree, please explain briefly.

    No response

5. We found the forecast information (precip amounts, pavement temperature, air temp, time of storm, etc.) from Foretell reliable. Agree or Disagree

    1 agreed 3 disagreed 3 no responses

6. If you answered disagree, please explain briefly.

    The times I used Foretell, start times were off and the amount of snow didn't match what we received.

    The times I have used Foretell I found them to be wrong a majority of the time.

    Prediction times were off 1 to 1 ½ hrs

    We have found that Foretell in not very accurate and sometimes it is behind time on the progress as the storm moves across. We have found that with storms that Meridian is right on with what is going to happen with the start time and end times and the amount of precip.

7. We found the forecast information (precip. amounts, pavement temperature, air temp, time of storm, etc.) from Meridian to be reliable. Agree or Disagree

    1 agreed 3 disagreed 3 no responses

8. If you answered disagree, please explain briefly.

    Once again, Meridian was wrong a majority of the time. Road temps were colder than predicted; Start times were off any where from 6 to 8 hrs. We find that Meridian is friendlier to use and is more accurate on its information about the storms

9. Are there features or information that you would like to see provided in Foretell forecasts?

    Closer weather forecasting, maybe by county.

    Longer real time data in Foretell.

10. Are there features or information that you would like to see provided in Meridian's forecasts?

    More accurate time of the storm.

4. SUMMARY AND CONCLUSIONS

This study examined two weather forecasting service providers for the Iowa DOT using various data to determine the accuracy of each of the forecasting services. Both weather forecasting services provided CTRE access to their databases for us to extract data for use in our analyses, for which we offer our thanks.

Each of the weather forecasting services provides their own unique perspectives to forecasting weather events. The Foretell service issues forecasts at 03:00, 09:00, 15:00, and 21:00 with a forecast term of 30 hours. The Meridian service issues forecasts at 04:00, 12:00, 20:00, for a forecast term of 24 hours, with additional forecasts generated if conditions warrant them. The Foretell service is an automated service providing computer-generated forecasts. The Meridian service, however, includes human interpretation with its computer-derived forecasts. For our study, we used the last forecasts issued, by each service, just prior to a verified precipitation event. For example, if snow occurred at 02:00 at a given location, then the forecasts that were used would be the Foretell forecast issued at 21:00, and the Meridian forecast issued at 20:00.

In summary, of the data we collected, we show that there were 118 forecast start times from Meridian, with 17 precipitation event start times not forecasted. The data further show that there were 61 forecasted start times from Foretell with 64 event start times not forecasted. The mean difference in the predicted start time for a precipitation event from the Meridian service is 107.8 minutes. The mean difference in the predicted start time for a precipitation event from the Foretell services is 176.9 minutes.

With regard to the predicted ending time of the storm events, the data show that there were 118 forecast ending times from Meridian, with 17 precipitation event ending times not forecasted. The data further show that there were 60 forecasted ending times from Foretell with 64 event ending times not forecasted, and 10 model runs not completed. The mean difference in the predicted ending time for a precipitation event from the Meridian service is 177.1 minutes. The mean difference in the predicted ending time for a precipitation event from the Foretell services is 266.6 minutes.

Regarding the forecast hit rates, or when the weather services predicted precipitation, and precipitation was observed, the data show that Meridian agreed with the ASOS system 91 percent of the time. Foretell agreed with the ASOS system 60 percent of the time. Furthermore, the data show that Meridian agreed with the garage reports at an average of 90 percent, while the Foretell agreed with the garage reports at an average of 54 percent.

With regard to the precipitation reports, the data show that all garages under-reported the average snowfall by 0.46 inches. The National Weather Service snowfall amount difference was an average 0.16. The liquid equivalent amounts of precipitation as reported by Foretell indicate that Foretell over-reported the liquid equivalent amounts by an average of 0.05 inches, compared to the ASOS reports. The standard deviation for the liquid equivalent was 0.31 inches.

Regarding the pavement temperature comparisons, the data for Meridian show an average pavement temperature difference of 2.46 degrees Fahrenheit for all reporting locations. The data also show that the Meridian pavement temperatures are reporting an average of 0.76 degrees Fahrenheit colder than the RWIS sensors, with a standard deviation of 1.19 degrees. The Foretell comparisons show an average pavement temperature difference of 5.86 degrees Fahrenheit for all locations. The data also show that the Foretell pavement temperatures are reporting an average 0.33 degrees warmer than the sensors, with a standard deviation of 3.82 degrees.

In the area of user acceptance, it is difficult to draw firm conclusions due to the lack of formal responses from the garage. Generally, the garages wish that both services were more accurate in their forecast predictions for when the storm events will arrive and their duration.

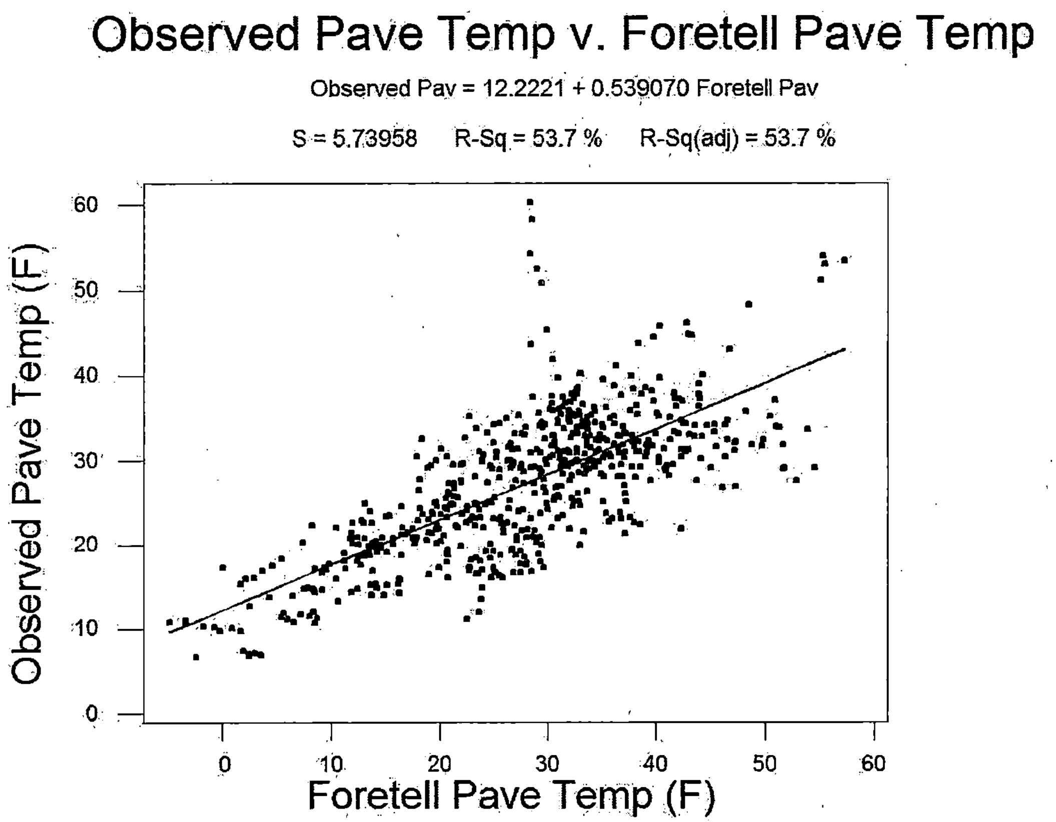
Both weather forecasting services have their own unique characteristics. Foretell is an Internet-based system with an eye-catching GUI. The service is fully automated and the complete forecast can be captured from a PC. The model runs that did not forecast precipitation are a concern. Part of this is due the format of issuing forecasts four times a day. More updates would be preferable. Foretell's pavement temperature prediction model, however, needs improvement. The data show an average of 5.86 degrees F difference, with some wide spreads in the data.

The Meridian service provides its forecasts over the Internet as well. Its data is presented in more of a text format, but it provides radar images and temperature information. The service also provides the customer with a narrative from the forecaster, describing what he or she thinks will happen over the length of the forecast. With regard to the forecast hit rates, 14% of the Meridian runs were missing for our evaluation. Meridian's pavement temperature prediction model faired better, by more accurately forecasting the pavement temperature.

The data provided in this study are generally considered to be of acceptable quality, and therefore suitable for data users. The descriptive statistics are provided to inform the user of the data quality and reliability.

APPENDIX A: OBSERVED PAVEMENT TEMPERATURES VS. FORECASTED TEMPERATURES

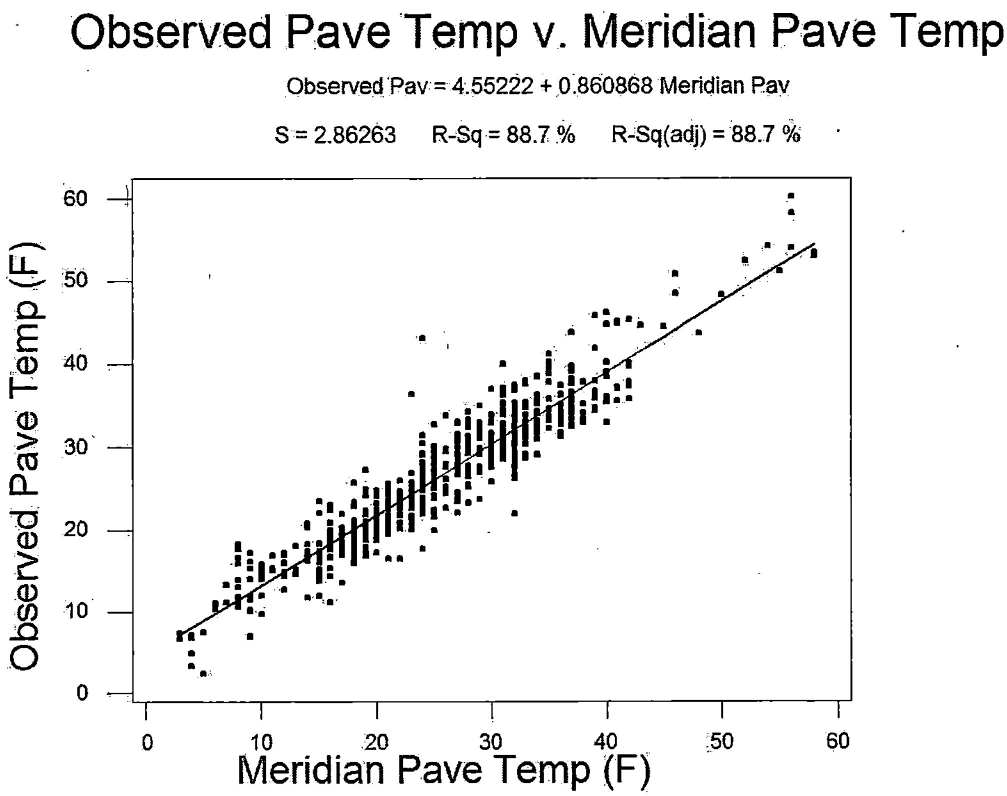
Foretell Pavement Temperature



N=608 observations

Figure 1. Forecasted Foretell pavement temperatures vs. observed pavement temperatures

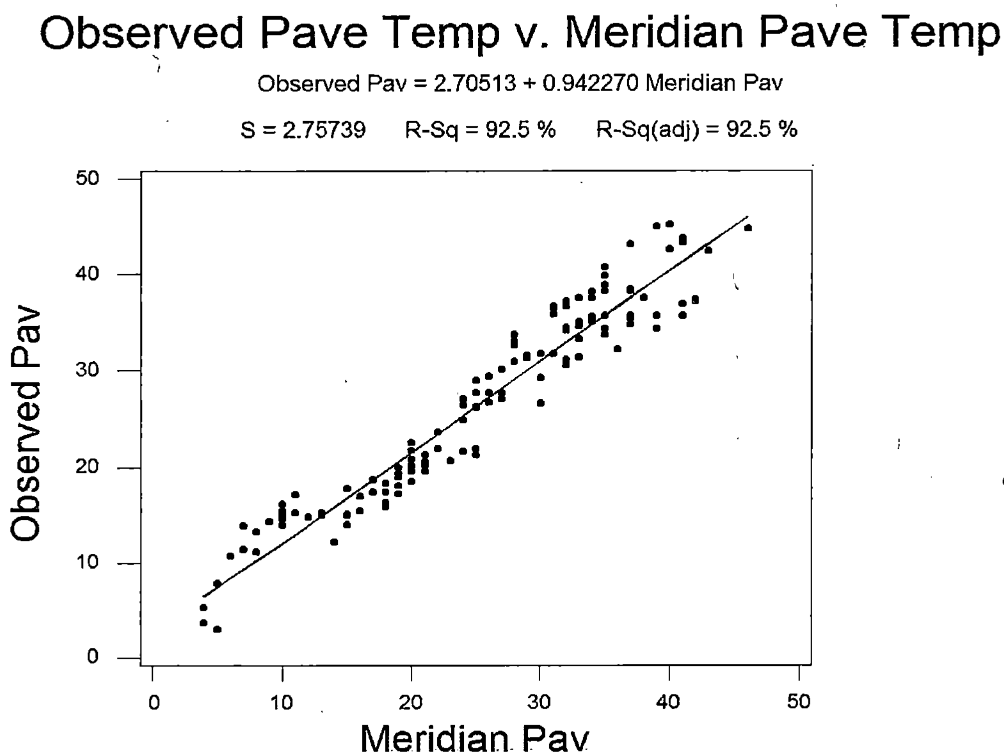
Location: Altoona

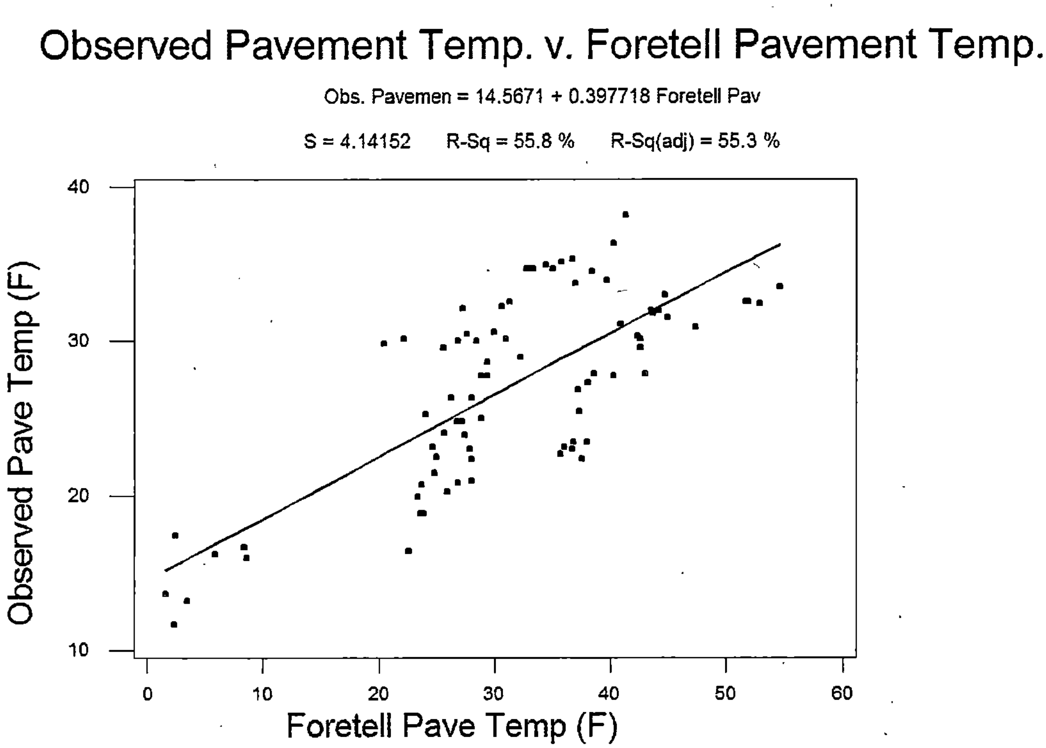


N = 693 observations

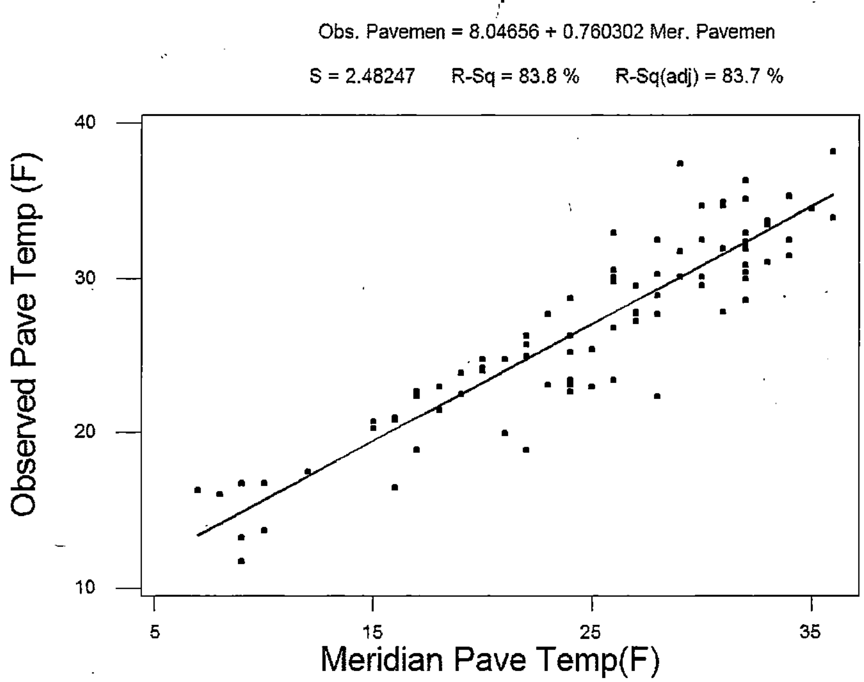
Figure 2. Forecasted Meridian pavement temperatures vs. observed pavement temperatures

Location: Cedar Rapids

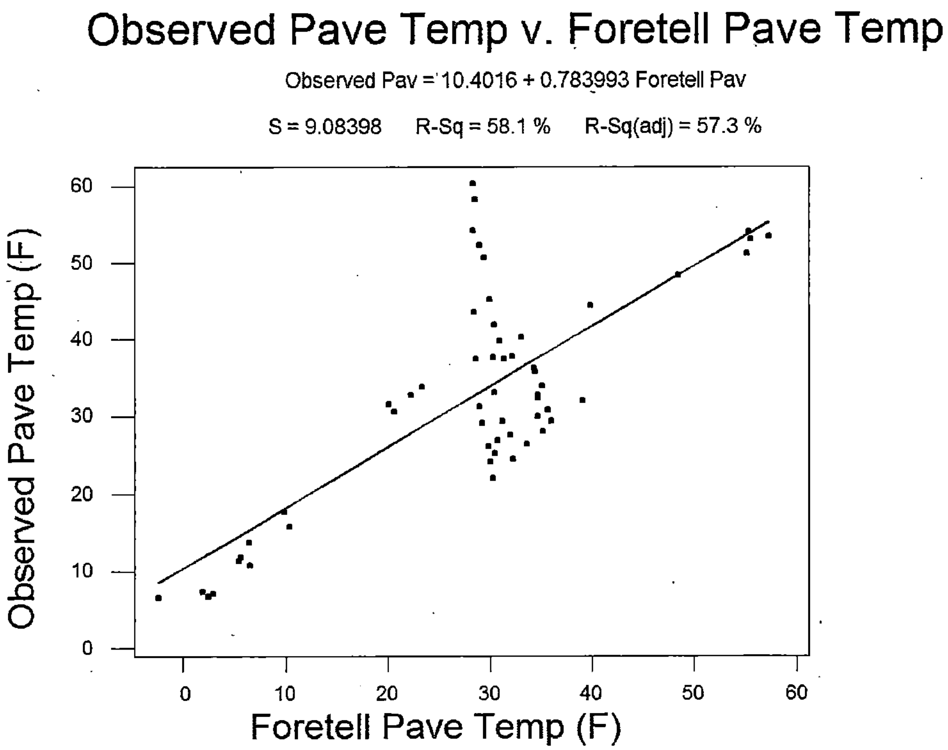


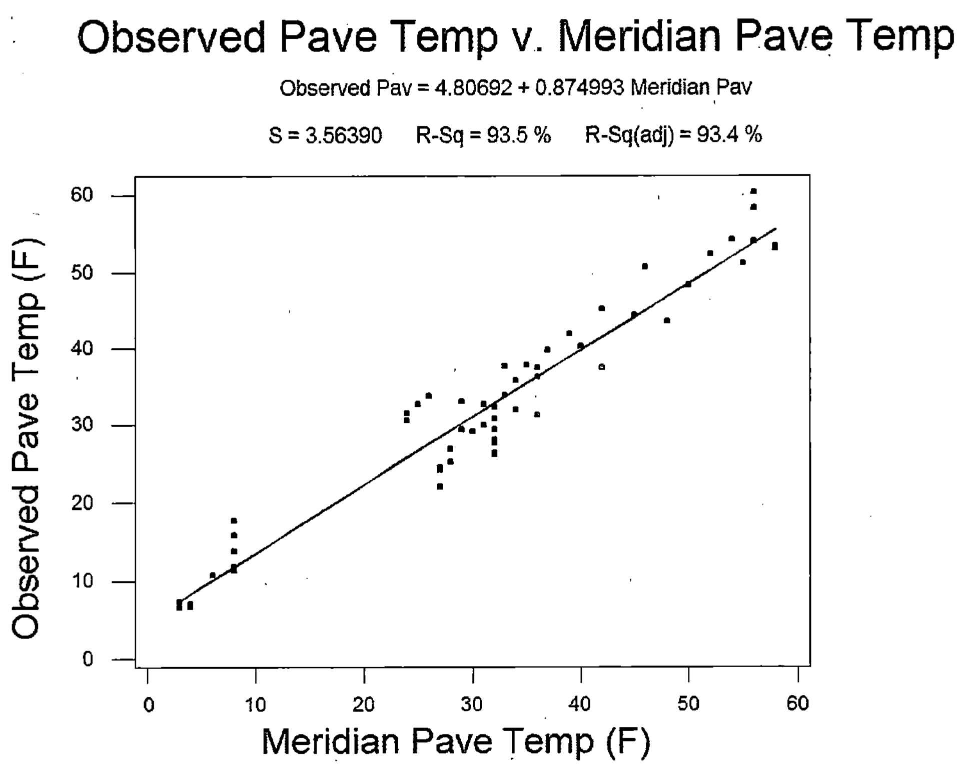


Observed Pavement Temp. v. Meridian Pavement Temp.

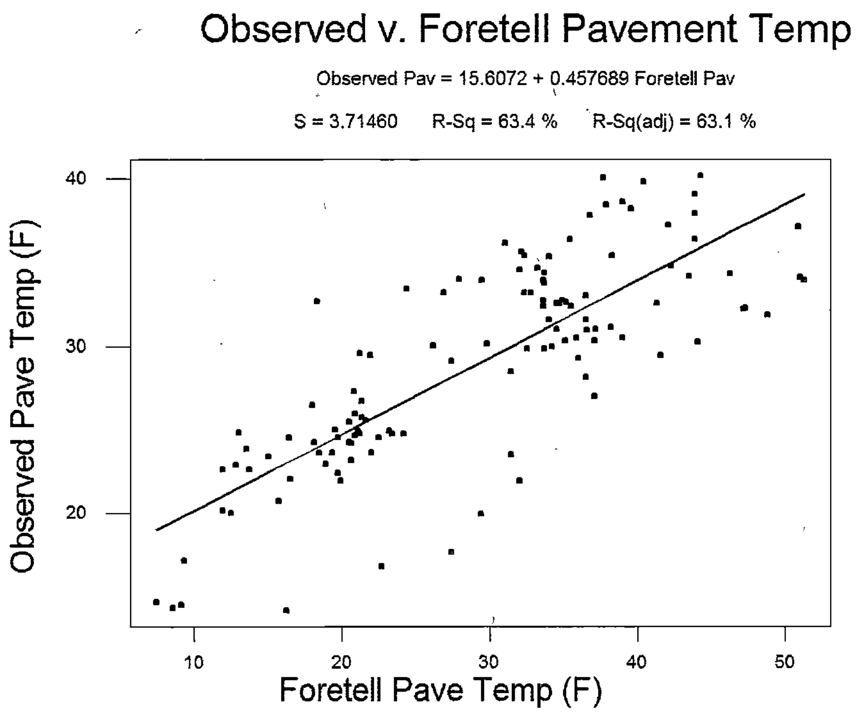


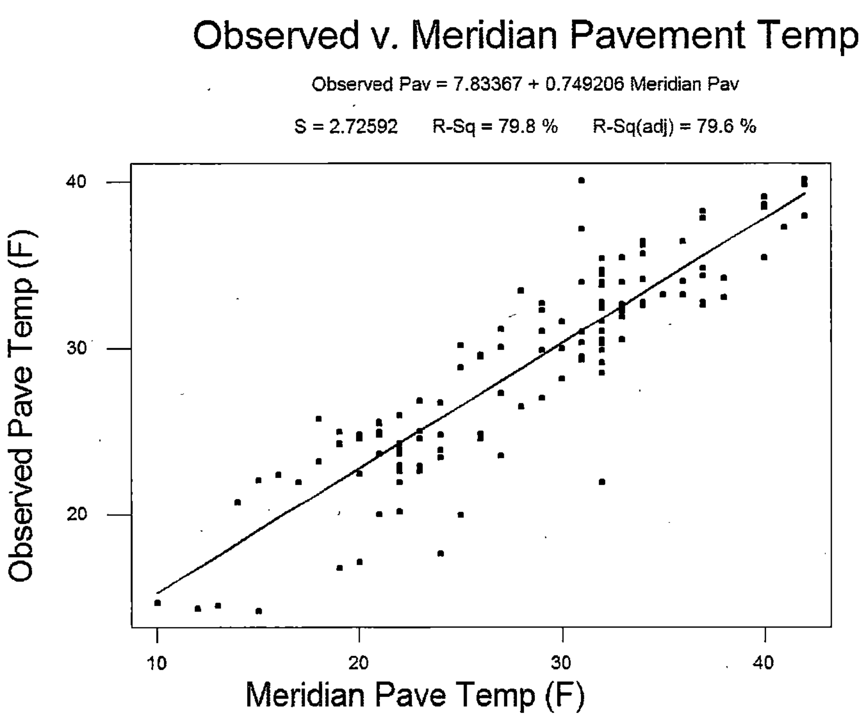
Location: Council Bluffs



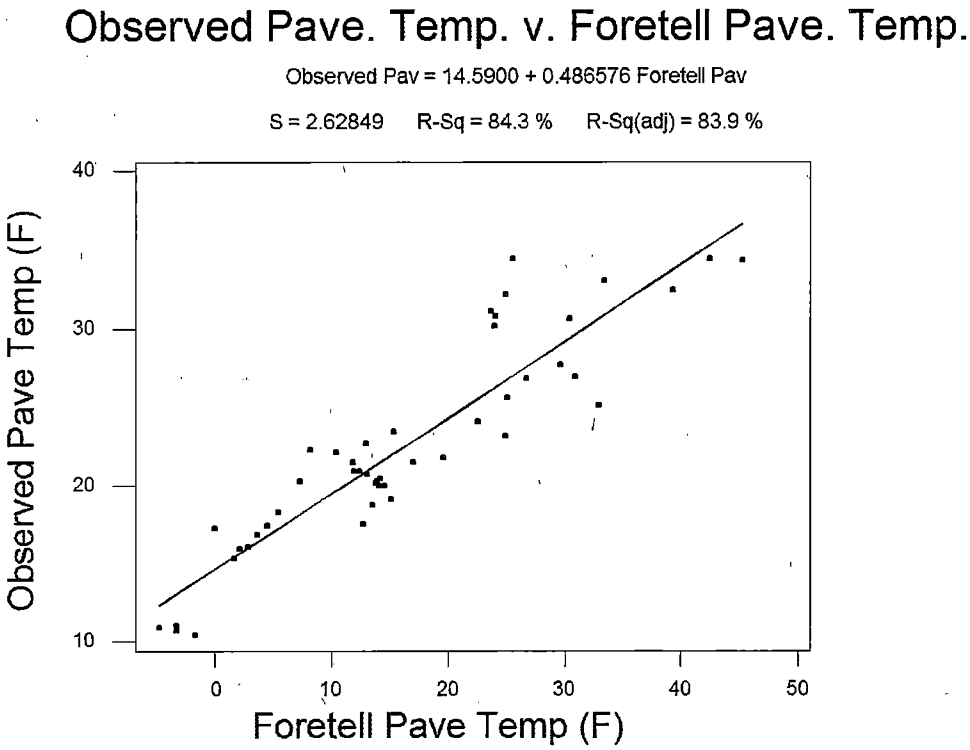


Location: Davenport





Location: Missouri Valley

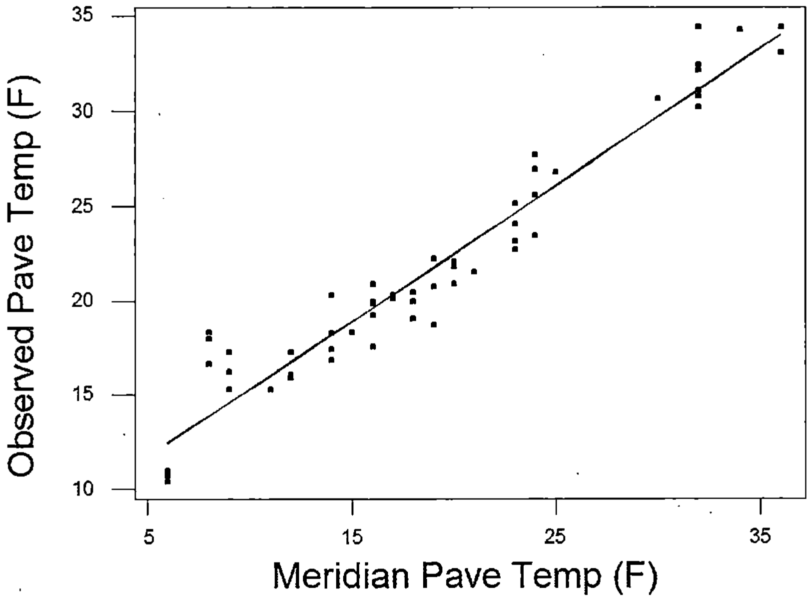


Location: Oakdale

Observed Pave. Temp. v. Meridian Pave. Temp.

Observed Pav = 8.11353 + 0.719080 Meridian Pav

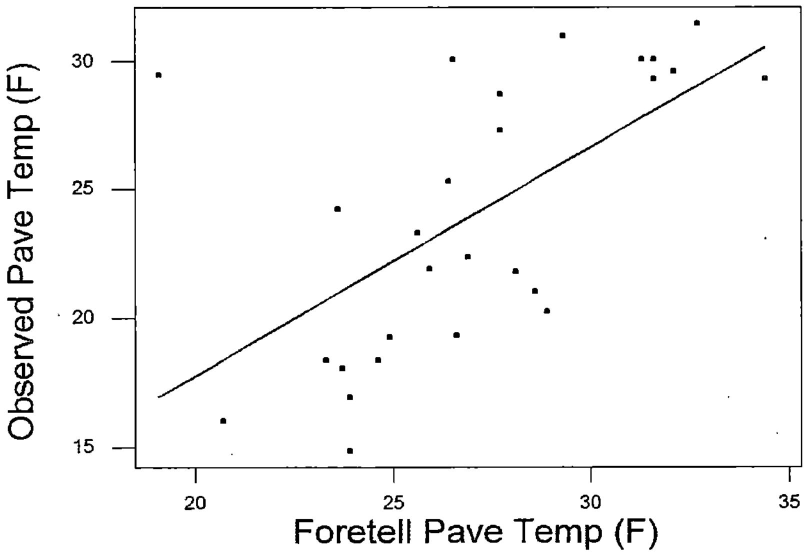
S = 1.63079 R-Sq = 93.3 % R-Sq(adj) = 93.2 %



Observed Pave Temp v. Foretell Pave Temp

Observed Pav = 0.0634134 + 0.885797 Foretell Pav

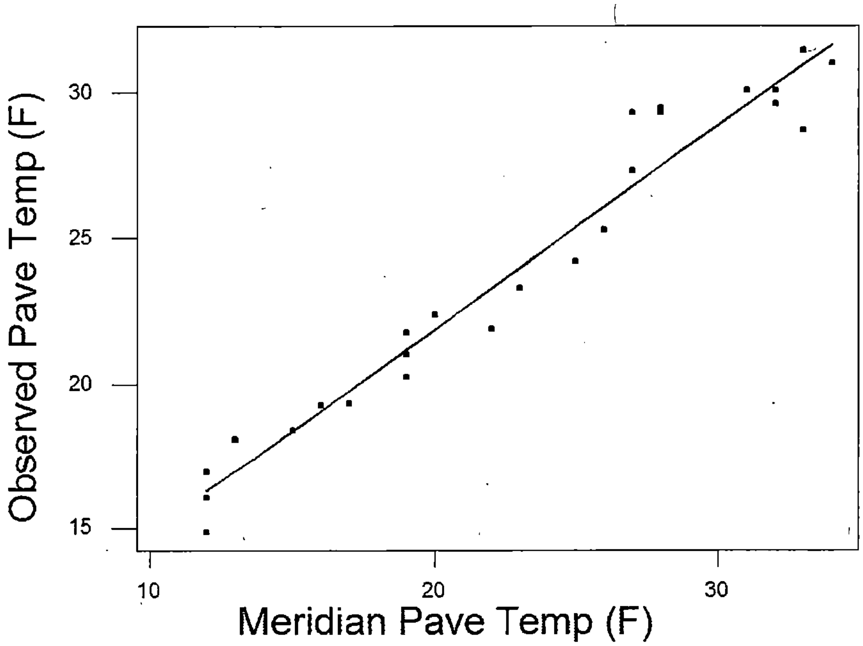
S = 4.29756 R-Sq = 37.9 % R-Sq(adj) = 35.4 %



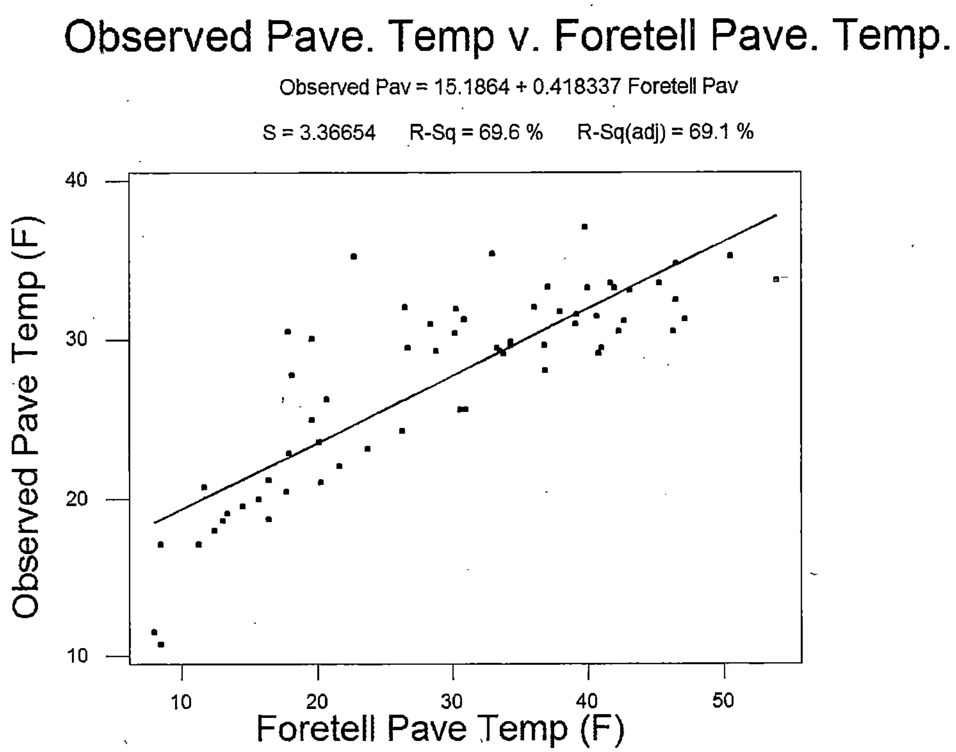
Observed Pave Temp v. Meridian Pave Temp

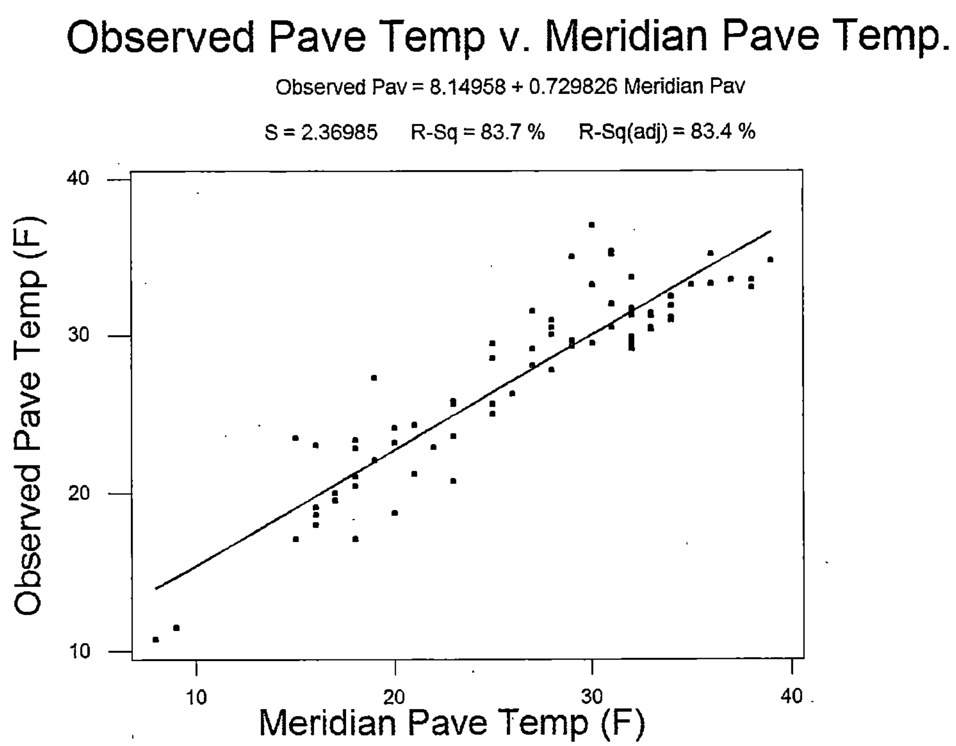
Observed Pav = 7.88404 + 0.699551 Meridian Pav

S = 1.10705   R-Sq = 95.9 %   R-Sq(adj) = 95.7 %



Location: Tipton



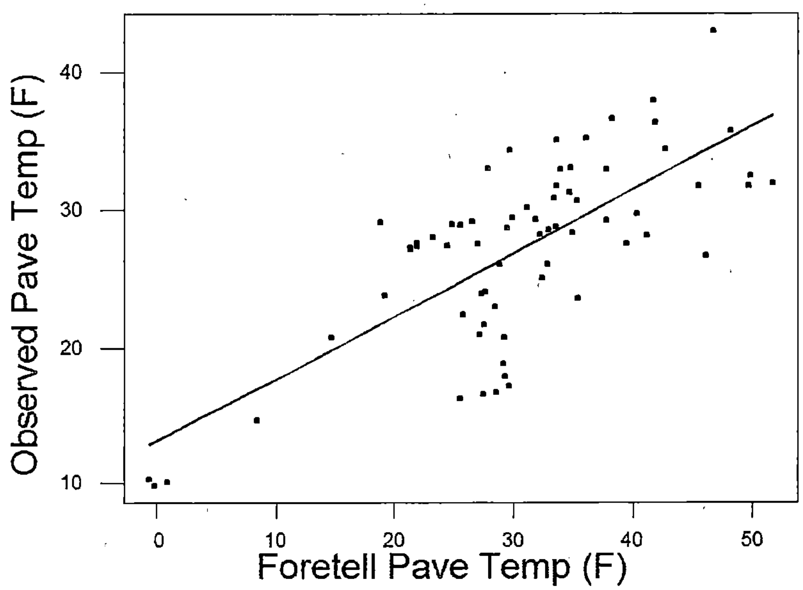


Location: Urbana

Observed Pave Temp v. Foretell Pave Temp

Observed Pav = 13.1250 + 0.460002 Foretell Pav

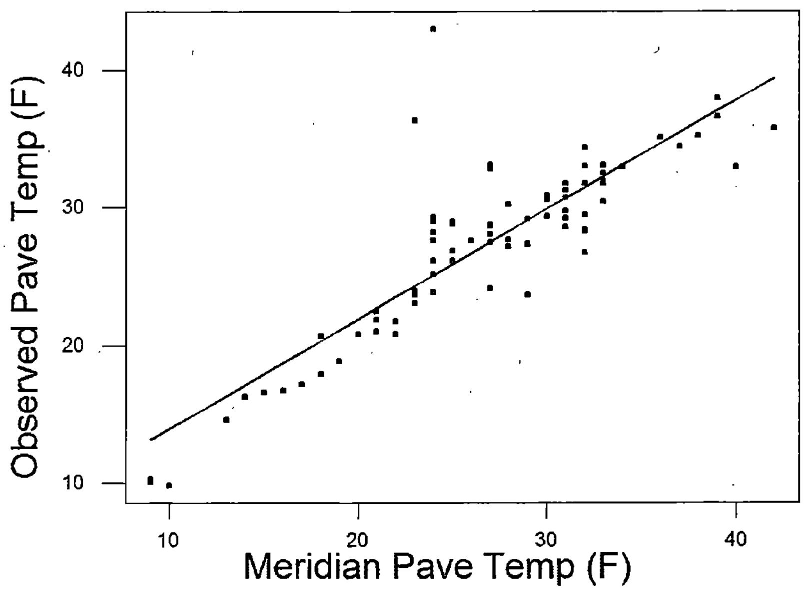
S = 4.66578 R-Sq = 53.2 % R-Sq(adj) = 52.5 %



Observed Pave Temp v. Meridian Pave Temp

Observed Pav = 5.97381 + 0.797029 Meridian Pav

S = 3.35572 R-Sq = 74.0 % R-Sq(adj) = 73.6 %

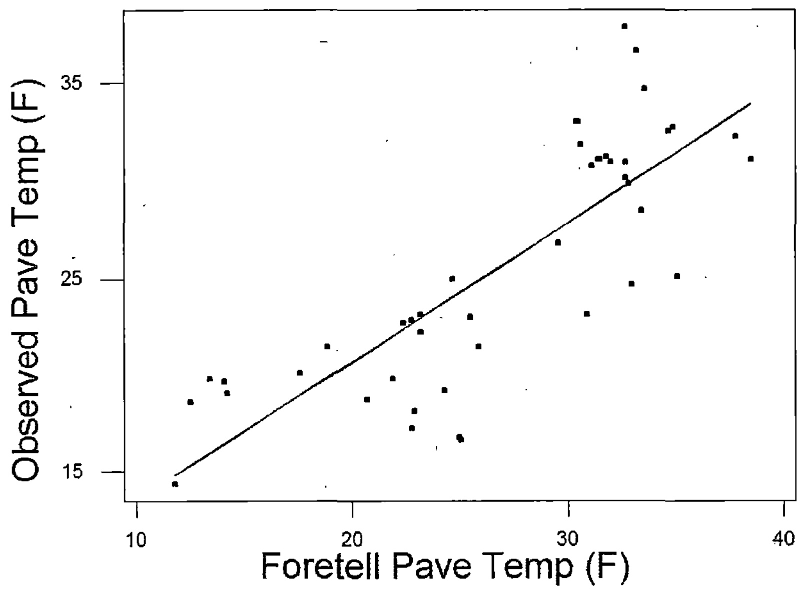


Location: Waterloo

Observed Pave Temp v. Foretell Pave Temp

Observed Pav = 6.35691 + 0.716312 Foretell Pav

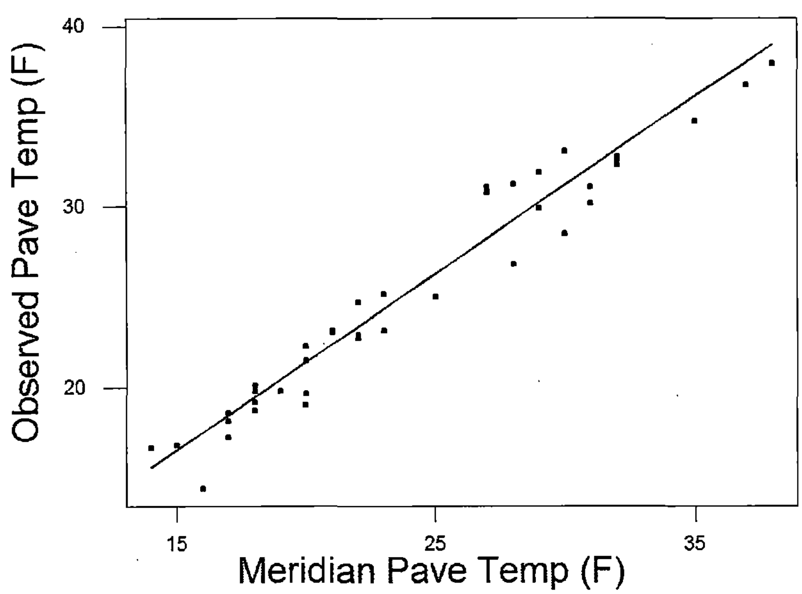
S = 3.73396 R-Sq = 65.8 % R-Sq(adj) = 64.9 %



Observed Pave Temp v. Meridian Pave Temp

Observed Pav = 1.85172 + 0.977693 Meridian Pav

S = 1.58583 R-Sq = 93.8 % R-Sq(adj) = 93.7 %



APPENDIX B: GARAGE COMPARISONS

Event Forecast Times: Altoona

Event Forecast Start Time

Date	Foretell	Meridian	Observed	Meridian Difference	Foretell Difference
12/2/2002	M	NF	7:45	n	n
12/2/2002	M	NF	9:30	n	n
12/20/2002	NF	13:00	18:00	300	n
01/4/2003	NF	9:00	9:00	0	n
1/5/2003	5:00	5:00	9:30	270	270.00
1/15/2003	0:00	21:00	20:30	30	210.00
1/18/2003	NF	2:00	1:00	60	n
1/22/2003	NF	6:00	4:00	120	n
1/25/2003	M	14:00	15:00	60	n
1/25/2003	NF	NF	22:20	n	n
2/3/2003	3:00	6:00	7:00	60	240.00
2/14/2003	21:00	21:00	22:30	90	90.00
2/23/2003	9:00	14:00	15:00	60	360.00
3/4/2003	NF	13:00	11:20	100	n
			Ave Error	104.5454545	234.00
			Std Dev	20.61553	135.2775

Event Forecast End Time

Date	Foretell	Meridian	Actual	Foretell Difference	Meridian Difference
12/2/2002	M	NF	9:00	n	n
12/2/2002	M	NF	13:00	n	n
12/20/2002	NF	15:00	20:00	n	300
1/4/2003	NF	16:00	6:45 (1/5)	n	645
1/5/2003	6:00	7:00	17:30	690.00	630
1/15/2003	7:00	7:00	8:00 (1/16)	60.00	60
1/18/2003	NF	4:00	7:00	n	180
1/22/2003	NF	12:00	6:00	n	360
1/25/2003	M	18:00	22:15	n	255
1/25/2003	NF	NF	8:00 (1/26/03)	n	n
2/3/2003	12:00	18:00	18:00	360.00	0
2/14/2003	23:00	8:00	14:00 (2/15)	900.00	360
2/23/2003	11:00	23:00	1:21 (2/24)	861.00	141
3/4/2003	NF	1:00	1:00 (3/5)	n	0
			Ave Error	574.20	266.4545
			Std Dev	301.1428	170.0301

M=Missing model data n=no difference to compare
NF=Not Forecasted

Event Forecast Times: Cedar Rapids

Event Forecast Start Time					
Date	Foretell	Meridian	Actual	Meridian Difference	Foretell Difference
12/5/2002	M	5:00	4:00	60	
12/20/2002	NF	13:00	16:00	180	
1/4/2003	14:00	13:00	13:30	30	30
1/18/2003	4:00	4:00	3:15	45	45
1/25/2003	M	14:00	15:30	90	
1/27/2003	NF	7:00	5:30	90	
1/28/2003	10:00	7:00	9:00	120	60
1/31/2003	NF				
2/14/2003	20:00	15:00	17:00	120	180
2/23/2003	20:00	18:00	19:19	79	39
3/3/2003	NF	9:00	9:30	30	
3/4/2003	14:00	13:00	13:00	0	60
			Ave Error	76.72727	69.00
			Std Dev	48.90	50.79

Event Forecast End Time					
Date	Foretell	Meridian	Actual	Meridian Difference	Foretell Diff.
12/5/2002	M	5:00	8:00	180	
12/20/2002	NF	0	22:00	120	
1/4/2003	17:00	15:00	17:00	120	0.00
1/18/2003	7:00	6:00	5:30	90	150.00
1/25/2003	M	18:00	20:00	120	
1/27/2003	NF	11:00	9:00	120	
1/28/2003	18:00	18:00	16:00	120	120.00
1/31/2003	NF		10:00		
2/14/2003	12:00	3:00	12:00 (1/15)	540	0.00
2/23/2003	1:00	2:00	3:06 (2/24)	66	126.00
3/3/2003	NF	15:00	17:30	150	
3/4/2003	3:00	4:00	23:59	241	151.00
			Ave Error	169.73	91.17
			Std Dev	125.10	65.46

M=Missing model data
NF=Not forecasted

Event Forecast Times: Council Bluffs

Event Forecast Start Time

Date	Foretell	Meridian	Observed	Meridian Difference	Foretell Difference
12/4/2002	NF	15:00	15:15	15	
1/1/2003	NF	21:00	21:00	0	
1/18/2003	4:00	1:00	0:30	30	120
1/24/2003	NF	2:00	2:30	30	
1/28/2003	6:00	8:00	5:30	150	30
2/2/2003	NF	None	7:00		
2/14/2003	M	13:00	19:00	360	
2/23/2003	NF	7:00	8:00	60	
3/3/2003	NF	2:00	9:00	420	
			Ave Error	133.13	75.00
			Std Dev	165.77	63.64

Event Forecast End Time

Date	Foretell	Meridian	Observed	Meridian Difference	Foretell Difference
12/4/2002	NF	18:00	16:10	110	
1/1/2003	NF	7:00	1:00 (1/2)	360	
1/18/2003	8:00	2:00	5:00	180	180.00
1/24/2003	NF	6:00	5:00	60	
1/28/2003	7:00	13:00	7:30	330	30.00
2/2/2003	NF		15:00		
2/14/2003	M	10:00	11:00 (2/15)	60	
2/23/2003	NF	18:00	16:00	120	
3/3/2003	NF	4:00	20:30	450	
			Ave Error	208.75	105.00
			Std Dev.	150.47	106.07

M=Missing model run
NF=Not forecasted

Event Forecast Times: Davenport

Event Forecast Start Time

Date	Foretell	Meridian	Observed	Meridian Difference	Foretell Difference
12/5/2002	NF	4:00	5:21	81	
12/20/2002	NF	NF	8:45		
1/4/2003	17:00	11:00	12:07	67	350.00
1/18/2003	4:00	5:00	4:53	7	53.00
1/25/2003	M	15:00	17:15	135	
1/28/2003	14:00	9:00	10:18	78	218.00
1/31/2003	22:00	0:00	1:33	93	213.00
2/9/2003	NF	00:00(2/10)	20:46	194	
2/11/2003	NF	NF	7:56		
2/11/2003	NF	14:00	16:06	126	
2/14/2003	9:00	16:00	14:03	123	300.00
2/23/2003	21:00	21:00	22:03	63	63.00
3/1/2003	7:00	5:00	5:42	42	78.00
3/1/2003	NF	1:00 (3/2)	22:32	152	
3/3/2003	NF	10:00	10:30	30	
3/4/2003	12:00	13:00	12:39	21	39.00
3/5/2003	NF	23:00	22:54	6	
			Ave Error	81.20	164.25
			Std. Dev.	56.07	121.86

Event Forecast End Time

Date	Foretell	Meridian	Observed	Meridian Difference	Foretell Difference
12/5/2002	NF	5:00	11:21	318	
12/20/2002	NF	NF	21:10		
1/4/2003	0:00	19:00	19:37	37	350.00
1/18/2003	6:00	7:00	6:58	2	58.00
1/25/2003	M	20:00	21:49	109	
1/28/2003	18:00	18:00	17:41	19	19.00
1/31/2003	5:00	7:00	8:55	115	235.00
2/9/2003	NF	8:00	5:51 (2/10)	129	
2/11/2003	NF	NF	9:53		
2/11/2003	NF	17:00	19:53	173	
2/14/2003	M	3:00 (2/15)	22:48	288	
2/23/2003	23:00	3:00	4:07 (2/24)	67	307.00
3/1/2003	9:00	11:00	8:42	138	18.00
3/1/2003	NF	3:00 (3/2)	23:42	198	
3/3/2003	NF	17:00	17:54	54	
3/4/2003	3:00	5:00	2:48 (3/5)	132	12.00
3/5/2003	NF	2:00	3:24 (3/6)	84	
			Ave Error	124.20	142.71
			Std. Dev.	91.11	149.22

Event Forecast Times: Martensdale

Event Forecast Start Time					
Date	Foretell	Meridian	Observed	Meridian Difference	Foretell Difference
12/5/2002	NF	4:00	5:00	60	
1/4/2003	14:00	10:00	9:00	60	300
1/15/2003	NF	21:00	20:15	45	
1/18/2003	3:00	NF	5:00		120
1/22/2003	NF	6:00	5:30	30	
1/25/2003	M	19:00	3:45	1005	
1/27/2003	8:00	2:00	3:00	60	300
1/28/2003	9:00	8:00	10:00	120	60
2/3/2003	9:00	13:00	12:30	30	150
2/8/2003	M	6:00	10:15	255	
2/9/2003	20:00	13:00	13:00	0	420
2/10/2003	NF	5:00	6:00	60	
2/10/2003	NF	22:00	22:30	30	
2/14/2003	NF	5:00	6:30	30	
2/14/2003	NF	13:00	13:00	0	
2/14/2003	NF	NF	18:45		
2/23/2003	18:00	15:00	15:45	45	135
3/3/2003	12:00	5:00	9:30	270	150
3/4/2003	9:00	9:00	11:00	120	120
			Ave. Error	130.59	195.00
			Std. Dev.	238.34	117.15

M=Missing Model run
NF=Not forecasted

Storm Forecast Times: Martensdale (Continued)

Event Forecast End Time

Date	Foretell	Meridian	Observed	Meridian Difference	Foretell Difference
12/5/2002	NF	7:00	9:10	130	
1/4/2003	17:00	18:00	11:00	420	360
1/15/2003	NF	7:00	7:00 (1/16)	0	
1/18/2003	5:00	NF	10:00		300
1/22/2003	NF	13:00	10:30	150	
1/25/2003	M	20:00	20:00	0	
1/27/2003	10:00	6:00	5:40	20	260
1/28/2003	15:00	17:00	16:00	60	60
2/3/2003	21:00	19:00	17:40	80	200
2/8/2003	M	8:00	11:20	200	
2/9/2003	4:00	16:00	20:00	240	360
2/10/2003	NF	7:00	8:00	60	
2/10/2003	NF	3:00	1:30 (2/11)	90	
2/14/2003	NF		10:30		
2/14/2003	NF	4:00	18:40	880	
2/14/2003	NF	11:00	15:30 (2/15)	270	
2/23/2003	1:00	23:00	23:40	40	80
3/3/2003	1:00	6:00	11:15	315	105
3/4/2003	10:00	22:00	12:30:00 AM (3/5)	870	750
Ave Error (minutes)				225.00	275.00
Std. Dev.				271.56	212.04

M=Missing model run
NF=Not forecasted

Event Forecast Times: Missouri Valley

Event Forecast Start Time

Date	Foretell	Meridian	Observed	Meridian Difference	Foretell Difference
12/4/2002	NF*	NF	10:00	*	*
1/1/2003	NF	15:00	19:25	265	
1/15/2003	NF	13:00	16:30	210	
1/18/2003	2:00	0:00	0:00	0	120
1/22/2003	NF	4:00	2:00	120	
1/24/2003	NF	2:00	3:00	60	
2/3/2003	3:00	5:00	6:40	100	220
2/14/2003	17:00	13:00	18:30	330	90
2/23/2003	14:00	5:00	7:30	150	390
	Ave Error (minutes)			154.375	205.00
	Std. Dev.			108.9376	135.2775

Event Forecast End Time

Date	Foretell	Meridian	Observed	Meridian Difference	Foretell Difference
12/4/2002	NF	NF	14:30		
1/1/2003	NF	3:00	23:30	210	
1/15/2003	NF	7:00	6:30(1/16)	30	
1/18/2003	5:00	1:00	7:00	360	120
1/22/2003	NF	12:00	11:00	60	
1/24/2003	NF	5:00	6:00	60	
2/3/2003	21:00	14:00	14:30	30	390
2/14/2003	0:00	8:00	10:30 (2/15)	150	630
2/23/2003	23:00	18:00	19:00	60	240
	Ave Error (minutes)			120.00	345.00
	Std Dev			115.6349	196.7232

M=missing model run
NF=Not forecasted

Event Forecast Times: Newton

Event Forecast Start Time					
Date	Foretell	Meridian	Observed	Meridian Difference	Foretell Difference
1/15/2003	NF	23:00	22:30	30	
1/27/2003	NF	3:00	2:17	43	
1/28/2003	8:00	7:00	8:00	60	0
2/14/2003	12:00	6:00	9:30	210	570
	Ave Error (minutes)			85.75	285
	Std. Dev				

Event Forecast End Time					
Date	Foretell	Meridian	Observed	Meridian Difference	Foretell Difference
1/15/2003	NF	7:00	5:30 (1/16)	90	
1/27/2003	NF	7:00	6:12	48	
1/28/2003	14:00	17:00	16:00	60	120.00
2/14/2003	13:00	4:00	2:30:00 PM(2/15)	90	90.00
	Ave Error (minutes)			72	105
	Std. Dev			21.35416	21.2132

M=Missing model run
NF=Not forecasted

Event Forecast Times: Oakdale

Event Forecast Start Time					
Date	Foretell	Meridian	Observed	Meridian Difference	Foretell Difference
1/27/2003	NF	7:00	5:30	90	
1/28/2003	12:00	7:00	8:51	111	189.00
3/4/2003	14:00	10:00	11:20	80	160.00
	Ave Error (minutes)			93.67	174.50
	Std.Dev.			15.82	20.51

Event Forecast End Time					
Date	Foretell	Meridian	Observed	Meridian Difference	Foretell Difference
1/27/2003	NF	11:00	8:00	180	
1/28/2003	19:00	12:00	16:28	268	180.00
3/4/2003	4:00	1:00	3:50 (3/5)	170	10.00
	Ave Error (minutes)			206.00	95.00
	Std Dev			53.93	120.21

M=Missing model run
NF=Not forecasted

Event Forecast Times: Sydney

Event Forecast Start Time					
Date	Foretell	Meridian	Observed	Meridian Difference	Foretell Difference
12/4/2002	NF	NF	14:00		
1/2/2003	NF	23:00	3:15	285	
2/3/2003	10:00	5:00	9:00	240	60
2/28/2003	1:00	21:00	21:00	0	240
			Ave Error	175	150
			Std. Dev	153.2155	127.2792

Event Forecast End Time					
Date	Foretell	Meridian	Observed	Meridian Difference	Foretell Difference
12/4/2002	NF	NF	16:00		
1/2/2003	NF	9:00	5:00	240	
2/3/2003	17:00	14:00	15:00	60	120
2/28/2003	4:00	23:00	23:00	0	300
			Ave Error	100	210
			Std Dev	124.9	127.2792

M=Missing model run
NF=Not forecasted

Event Forecast Times: Tipton

Event Forecast Start Time					
Date	Foretell	Meridian	Observed	Meridian Difference	Foretell Difference
12/3/2002	NF	NF	6:00		
1/4/2003	14:00	11:00	11:00	0	180.00
1/11/2003	NF	NF	16:00		
1/25/2003	NF	15:00	16:30	90	
1/27/2003	NF	8:00	6:00	120	
1/28/2003	6:00	8:00	9:30	90	210.00
2/1/2003	NF	NF	1:00		
2/3/2003	9:00	13:00	15:00	120	360.00
2/9/2003	0:00	23:00	22:00	60	120.00
2/11/2003	NF	14:00	8:00	360	
2/14/2003	11:00	15:00	14:30	30	210.00
2/23/2003	16:00	21:00	20:29	31	270.00
3/1/2003	NF	5:00	5:42	42	
3/3/2003	NF	9:00	10:00	60	
3/4/2003	9:00	13:00	13:00	0	240.00
3/6/2003	NF	NF	6:45		
3/7/2003	NF	5:00	5:45	45	
3/8/2003	9:00	8:00	10:30	150	90.00
			Ave Error	85.57	210.00
			Std Dev	90.91	84.85

M=Missing model run
NF=Not forecasted

Event Forecast Times: Tipton Continued

Event Forecast End Time					
Date	Foretell	Meridian	Observed	Meridian Difference	Foretell Difference
12/3/2002	NF	NF	9:00		
1/4/2003	15:00	19:00	20:30	90	330.00
1/11/2003	NF	NF	16:15		
1/25/2003	NF	20:00	21:00	60	
1/27/2003	NF	11:00	8:30	150	
1/28/2003	21:00	18:00	18:00	0	180.00
2/1/2003	NF	NF	11:30		
2/3/2003	11:00	22:00	21:30	30	600.00
2/9/2003	4:00	8:00	4:00 (2/10)	240	0.00
2/11/2003	NF	16:00	9:00	420	
2/14/2003	1:00	4:00	13:00 (2/15)	540	720.00
2/23/2003	18:00	3:00	3:00 (2/24)	0	540.00
3/1/2003	NF	10:00	9:00	60	
3/3/2003	NF	16:00	17:00	60	
3/4/2003	11:00	5:00	3:00 (3/5)	120	960.00
3/6/2003	NF	NF	7:30		
3/7/2003	NF	6:00	7:30	30	
3/8/2003	11:00	16:00	12:00	240	60.00
			Ave Error	145.71	423.75
			Std. Dev.	162.56	338.06

M=Missing model run
NF=Not forecasted

Event Forecast Times: Urbana

Event Forecast Start Time

Date	Foretell	Meridian	Observed	Meridian Difference	Foretell Difference
12/2/2002	NF	9:00	7:30	90	
12/20/2002	NF	13:00	17:00	240	
1/4/2003	15:00	12:00	12:00	0	180
1/18/2003	5:00	8:00	4:00	240	60
1/25/2003	NF	14:00	15:30	90	
1/27/2003	NF	6:00	4:00	120	
1/28/2003	15:00	7:00	9:00	120	360
1/31/2003	NF	NF			
2/3/2003	12:00	14:00	12:00	120	0
2/11/2003	17:00	13:00	14:30	90	150
2/14/2003	19:00	15:00	18:00	180	60
2/23/2003	23:00	16:00	18:00	120	300
3/1/2003	NF	0:00	2:30	150	
3/3/2003	NF	7:00	7:30	30	
3/4/2003	15:00	13:00	12:30	30	150
3/6/2003	NF	22:00	18:00	240	
3/8/2003	NF	6:00	10:30	270	
			Ave Error	133.13	157.50
			Std Dev	81.95	122.91

Event Forecast End Time

Date	Foretell	Meridian	Observed	Meridian Difference	Foretell Difference
12/2/2002	NF	13:00	10:00	180	
12/20/2002	NF	0:00	20:30	210	
1/4/2003	20:00	16:00	17:00	60	180
1/18/2003	6:00	9:00	6:00	180	0
1/25/2003	NF	18:00	19:30	90	
1/27/2003	NF	11:00	7:15	225	
1/28/2003	19:00	17:00	15:00	180	240
1/31/2003	NF	NF	7:00		
2/3/2003	22:00	21:00	11:00:00 AM (2/4)	840	780
2/11/2003	18:00	17:00	15:45	75	135
2/14/2003	6:00	23:00	2:30 (2/15)	210	210
2/23/2003	2:00	2:00 (2/23)	21:30	270	270
3/1/2003	NF	5:00	11:00	360	
3/3/2003	NF	15:00	18:00	180	
3/4/2003	4:00	3:00	23:30	210	270
3/6/2003	NF	0:00	22:30	90	
3/8/2003	NF	15:00	14:00	60	
			Average	213.75	260.63
			Std Dev	185.94	227.76

Event Forecast Times: Waterloo

Event Forecast Start Time					
Date	Foretell	Meridian	Observed	Meridian Difference	Foretell Difference
12/2/2002	NF	8:00	7:45	15	
1/4/2003	14:00	13:00	14:06	66	6
1/5/2003	16:00	0:00	0:01	1	540
1/14/2003	NF	0:00	0:43	43	
1/31/2003	-	-			
2/14/2003	19:00	14:00	18:19	259	41
3/3/2003	NF	7:00	6:00	60	
3/3/2003	NF	NF	7:30		
3/4/2003	13:00	7:00	6:04	64	420
			Ave Error	72.57	251.75
			Std Dev	85.97	268.46

Storm Forecast End Time					
Date	Foretell	Meridian	Observed	Meridian Difference	Foretell Difference
12/2/2002	NF	13:00	9:00	240	
1/4/2003	20:00	14:00	16:16	136	224
1/5/2003	18:00	3:00	8:00	300	780
1/14/2003	NF	1:00	2:47	107	
1/31/2003	NF	NF	7:00		
2/14/2003	2:00	23:00	0:22	82	98
3/3/2003	NF	NF	16:53		
3/3/2003	NF	15:00	18:00	180	
3/4/2003	23:00	20:00	21:11	71	119
			Ave Error	159.43	305.25
			Std Dev	85.43	321.26

M=Missing model run
N=Not forecasted

Garage Summary: Meridian Data

Meridian				Model-Actual	Model-Actual	Model-Actual	ASOS events not garage events	based on garage times
City	Number of garage events evaluated	Number of ASOS events evaluated	Number of false alarms	Liquid amount average diff	Garage snow amount average diff	ASOS snow amount average diff	ASOS hits/ ASOS totals	Garage hits/ garage totals
Altoona	14	31	11	-0.09	-0.28	-0.16	0.97	0.79
Cedar Rapids	11	32	13	0.01	-0.09	0.15	0.84	1.00
Council Bluffs	9	28	17	-0.01	-0.82	-0.42	0.96	0.89
Davenport	17	29	22	0.03	0.16	0.31	0.93	0.88
Martensdale	19	31	11	0.01	0.00	0	0.94	0.94
Missouri Valley	9	NA	NA		-0.23		NA	0.89
Newton	4	NA	NA		-3.44		NA	1.00
Oakdale	3	27	25	0.09	0.74	0.83	0.89	1.00
Sidney	4	NA	NA		-0.42		NA	0.75
Sioux City	1	32	18		-2.20		0.84	1.00
Tipton	18	27	25	0.01	-0.28	-0.17	0.85	0.78
Urbana	16	23	20	0.02	0.06	0.08	0.87	1.00
Waterloo	8	23	24	-0.02	-0.21	-0.19	0.96	1.00
AVERAGES			**18.60**	**0.01**	**-0.54**	**0.05**	**0.91**	**0.92**
Standard Deviations			**5.52**	**0.05**	**1.10**	**0.36**	**0.05**	**0.10**

Garage Summary: Foretell Data

Foretell						Model-Actual		ASOS events not garage events
City	**Number of garage events evaluated**	**Number of ASOS events evaluated**	**Number of false alarms < 15 hrs**	**Number of false alarms > 15 hrs**	**Total false alarms**	**Liquid amount average diff.**	**Snow amount diff.**	**ASOS hits/ ASPS totals**
Altoona	11	31	5	6	8	-0.39	NA	0.58
Cedar Rapids	9	32	4	8	9	0.04	NA	0.56
Council Bluffs	8	28	9	7	13	0	NA	0.61
Davenport	16	29	7	15	17	-0.02	NA	0.38
Martensdale	17	31	10	15	17	-0.06	NA	0.71
Missouri Valley	9	NA	NA	NA	NA		NA	NA
Newton	4	NA	NA	NA	NA		NA	NA
Oakdale	3	26	8	14	15	0.26	NA	0.62
Sidney	4	NA	NA	NA	NA		NA	NA
Sioux City	1	31	7	11	13		NA	0.55
Tipton	18	27	6	12	14	-0.05	NA	0.59
Urbana	16	23	9	3	11	0.08	NA	0.65
Waterloo	8	23	8	10	13	-0.07	NA	0.74
AVERAGES			**7.30**	**10.10**	**13.00**	**-0.02**	**NA**	**0.60**
Standard Deviation			**1.89**	**4.07**	**3.02**	**0.17**		**0.10**

Garage Summary: Foretell Data Continued

Based on garage times	Compared to ASOS	Model-Actual								
Garage hits/garage totals	**Type hits/ tot hits**	**Pave temp bias**	**Pave temp average diff.**	**Garage start average diff.**	**Garage end average diff.**	**ASOS start bias mer - ASOS**	**ASOS end bias**	**ASOS start average diff.**	**ASOS end average diff.**	**City**
0.45	1.00	-1.6	4.5	234.0	574.2	-48.3	-525.3	257.0	554.7	Altoona
0.75	0.94	6.6	8.3	69.0	91.2	59.3	56.1	85.3	106.4	Cedar Rapids
0.25	1.00	-4.3	7.7	75.0	105.0	-303.0	-248.0	303.0	248.0	Council Bluffs
0.50	0.91	0.3	5.6	164.3	142.7	-84.1	-114.5	113.4	219.5	Davenport
0.53	1.00	NA	NA	195.0	275.0	148.8	59.7	234.1	257.9	Martensdale
0.44	NA	-6.4	8.1	205.0	345.0	NA	NA	NA	NA	Missouri Valley
0.50	NA	NA	NA	285.0	105.0	NA	NA	NA	NA	Newton
0.67	0.88	3.0	4.3	174.5	95.0	32.5	412.5	21.7	275.0	Oakdale
0.50	NA	-1.0	3.4	150.0	210.0	NA	NA	NA	NA	Sidney
1.00	1.00	NA	NA	240.0	300.0	360.0	540.0	360.0	540.0	Sioux City
0.44	1.00	2.0	6.7	210.0	423.8	-170.6	-96.3	247.1	312.0	Tipton
0.50	0.93	3.4	6.7	157.5	260.6	153.7	217.3	186.3	217.1	Urbana
0.50	0.94	1.3	3.5	251.8	305.3	-42.3	-127.0	236.2	244.0	Waterloo
0.54	**0.96**	**0.33**	**5.86**	**185.46**	**248.67**	**10.60**	**17.45**	**204.41**	**297.46**	
0.18	**0.05**	**3.82**	**1.88**	**63.95**	**145.77**	**185.86**	**314.22**	**103.61**	**142.04**	

GLOSSARY

ASOS The Automated Surface Observing System (ASOS) is a surface weather observing system being implemented by the National Weather Service (NWS), the Federal Aviation Administration (FAA), and the Department of Defense (DoD). ASOS is designed to support aviation operations and weather forecasting.

AWOS Automated Weather Observation System is mesoscale network implemented by the Iowa DOT to enable forecasters receive some of the same weather information that is available through ASOS, including visibility, barometric pressure, cloud height, temperature, dew point and wind data.

RWIS Roadway Weather Information System is a network of sensors located in and along Iowa's interstate and primary roads. These sensors are designed to provide Iowa DOT with specific weather information they need about the roadway. The weather information that these sensors provide includes surface temperature (at the roadway), subsurface temperature, air temperature, relative humidity, wind speed, wind direction, and precipitation

NWS The National Weather Service ™ (NWS) provides weather, hydrologic, and climate forecasts and warnings for the United States, its territories, adjacent waters, and ocean areas, for the protection of life and property and the enhancement of the national economy. NWS data and products form a national information database and infrastructure, which can be used by other governmental agencies, the private sector, the public, and the global community. The NWS provides warnings and forecast of hazardous weather, including thunderstorms, flooding, hurricanes, tornadoes, winter weather, tsunamis, and climate events. The NWS is the sole United States official voice for issuing warnings during life-threatening weather situations.